Electrical West

The Journal of ELECTRICITY POWER AND GAS

DEVOTED TO THE CONVERSION, TRANSMISSION AND DISTRIBUTION OF ENERGY.

276 A9

VOLUME XI

JANUARY-DECEMBER

1901

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SAN FRANCISCO, CALIFORNIA

The Snoqualmie Falls Transmission

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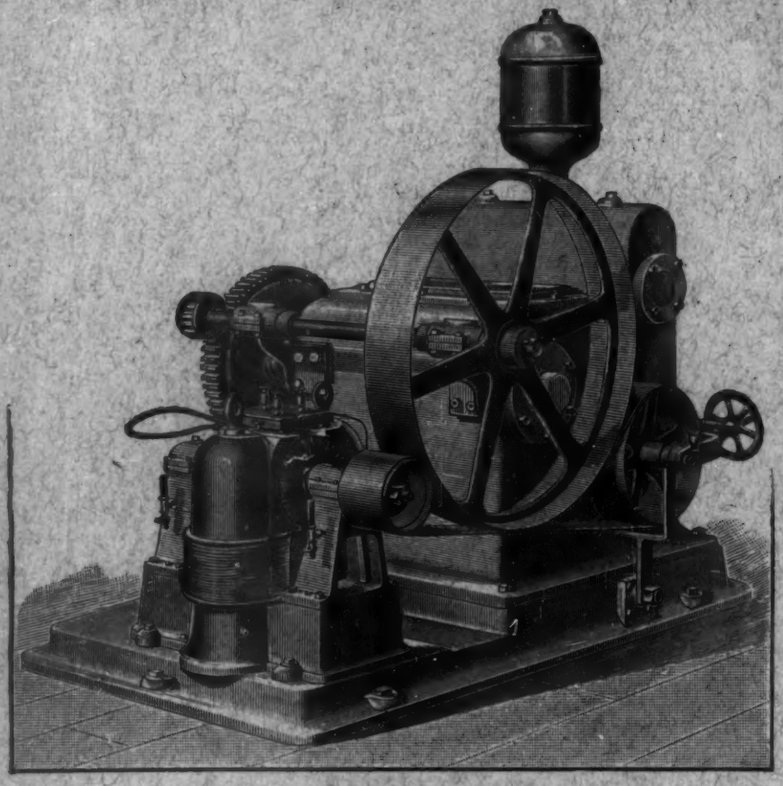

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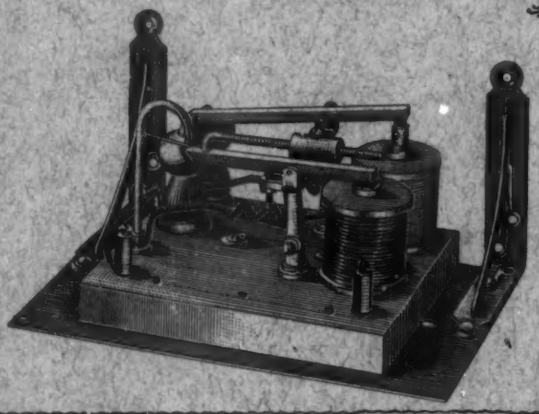

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SNOQUALMIE FALLS, WASHINGTON

FRONTISPIECE TO VOLUME XI OF THE
JOURNAL OF ELECTRICITY, POWER AND GAS

THE JOURNAL OF ELECTRICITY, POWER AND GAS.

Devoted to the Conversion, Transmission and Distribution of Energy.

VOLUME XI. SAN FRANCISCO, JANUARY, 1901. NUMBER 1.

The Power Transmission From Snoqualmie Falls.

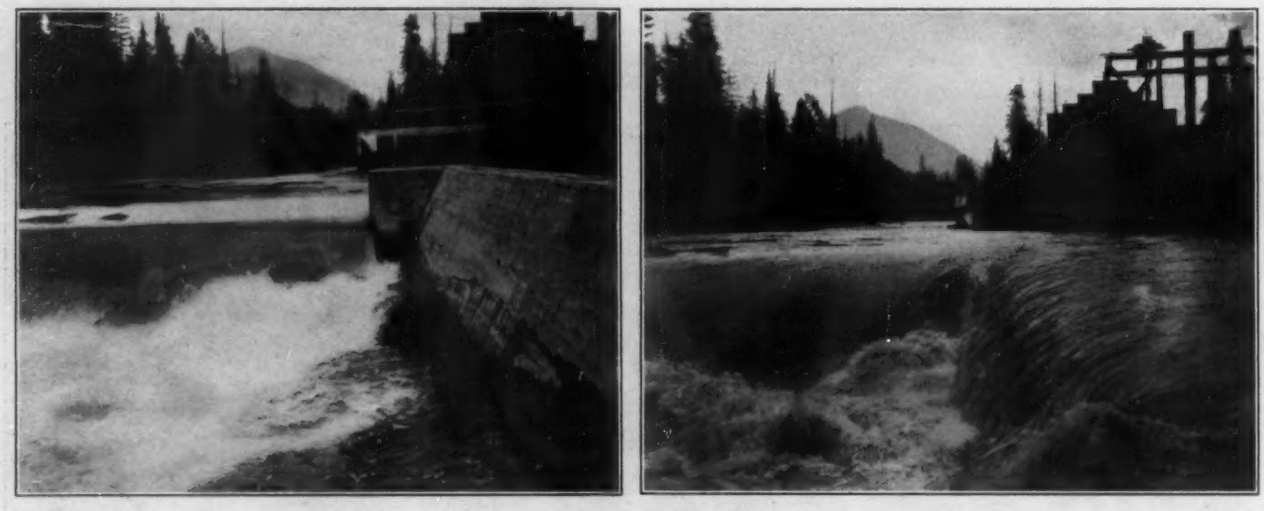
STANDING on the lower end of Goat Island and looking across Niagara toward Prospect Point, one sees, something less than two hundred feet away, Luna Island, which, though seemingly atilt on the brink of the cataract, marks off for itself a goodly portion of the great American waterfall. This portion about equals the Snoqualmie Falls in width, and the water flowing over is at times about equaled by that of Snoqualmie. Again, this portion of Niagara plunges over a peculiar shelf-like formation in the river bed so as to form the Cave of the Winds behind the cataract. To enter the cave one descends the face of Goat Island to the rocky brink of the lower river. It was a mockery to have donned the great yellow oilskins, for the spray drives so terrifically that it

THE CREST OF SNOQUALMIE FALLS.

goes through them as sieves. The lumberingly heavy felt slippers however, give sure footing, and, with wrists gripped to wrists, as boys "crack the whip," the guide leads the way along a staunch, green, "frog"-slimed timber foot-bridge thrown from rock to rock across the front of the very toe of the falls and into the lea where Luna Island has parted the waters. Then timorously we proceed on to the starting point through the Cave of the Winds, once within which one comes to the fullest realization of the insignificance of man. Beneath, a narrow declining ledge affords the pathway and threatens to slip one off into the seething cauldron; above, the rock that overhangs menaces, for sooner or later it must collapse under the weight of the tons of water that fall over it in a crest twenty feet in depth; behind, barriers the solid basalt of the river bed; in front there is the equally impenetrable, though translucent, barrier of falling water. Deafened by an awful roar which would stifle that of the combined artilleries of the world, fairly terrified by the

gusts of hurricane violence that, spray ladened, beat and baffle and blind every step, at last one emerges and, with a prayer of thanksgiving, realizes that he has become possessed of a greater appreciation of the value of the energy of Niagara than he ever had before.

But Snoqualmie Falls is a full hundred feet higher than Niagara, and did it possess a Cave of the Winds no human being, however protected, could exist for a moment within it. The volume of spray from Snoqualmie's appalling leap is a hundred times greater than that from Niagara. Adown the canyon sides below the fall, from near their tops, gathers moisture as from countless cropping springs. Thence trickle tiny streams that, as they descend, grow to rivulets and on to floods as the river far below is reached. All this, with the matchless verdure of the canyon and the gorgeous colorings of the bluffs, is due to the enormous precipitation of mist from the falls. Well do I remember when, sitting on the veranda of the President's cottage one sunset in May, I watched the mist as it rose everlastingly, as lightly as steam, from the falls up to a strata several hundred feet above whence a gentle wind took it down the valley, over the mighty forests of matchless Washington timber for miles and miles as far as the eye could reach, in a vapory veil of pearly whiteness. Such a mighty flood, leaping down that fearful height, betokens an enormous energy of which those miles and miles of trailing mist were but a trifling token. Of Snoqualmie it must be written that neither tongue nor pen nor lens nor brush can convey a suggestion, however slight, of the incomparable individuality of its beauteous grandeur. You must see it, you must hear it, or you will never know what it is like. It is the energy of this giant cataract that has been turned to industrial purpose through engineering means of such striking boldness and originality as to give warrant to the assurance that the Snoqualmie Falls transmission is one of the most interesting that the engineering practice of America, if not of the world, has ever known.—THE EDITOR.



PIER AND SPILLWAY AT SOUTH END OF DAM DURING LOW WATER AND DURING HIGH WATER, RESPECTIVELY.

TOPOGRAPHICAL AND METEOROLOGICAL.

BY CHARLES H. BAKER.

AT the apex of an isosceles triangle having for its base a straight line drawn through the cities of Tacoma, Seattle and Everett, with Seattle midway, is situated the famous Snoqualmie cataract. About twenty-five miles back from the shores of Puget Sound in the foothills of the Cascade Mountains, this grand spectacle in nature has for years attracted the sightseer, but the utilitarian saw no beauty in the picture until the long-distance transmission of power by electricity became possible. This waterfall and the adjacent land on both sides of the Snoqualmie River were purchased in the fall of 1897 and early in 1898 the Snoqualmie Falls Power Company was organized. Soon thereafter a heavy construction plant consisting of large boilers, steam hoisting machinery and a ten-drill air-compressor plant was installed at Snoqualmie Falls at the site of the proposed headworks. The first drill began operating April 17th, 1898, and thereafter the work was prosecuted day and night and Sundays until the work was finally completed. It has been of incalculable advantage to the company having the Seattle & International Railway pass within fifty feet of the works. A heavy trestle was constructed, spanning the railway, upon which a steel carrier is operated, by which means all the heavy machinery was lifted from the cars and transferred to the works.

The first water wheel and generator were in actual operation and delivered current into Seattle on the evening of July 31, 1899, and into Tacoma November 1, 1899. This event marked the successful completion of a project which throughout had been unattended by any fatality or serious accident. The design and execution of the plant is replete with original features, never before exploited in power transmission, conspicuous among them being the subterranean power house.

The Snoqualmie water-shed has an individuality peculiar to itself, which accounts for the large low-water flow of the river as compared with other rivers on the western slope, the relative sizes of the drainage areas being taken into account. The company, in the early stages of its operation, placed a party in the field for the purpose of exploring this water-shed with a view of determining its hydrographic, geological, geographical and meteorological features.

The main Snoqualmie River is formed by three large forks originating at the summits of the Cascade Mountains and flowing westward to the point of confluence about three miles above Snoqualmie Falls. These rivers have their origin in the regions of perpetual snow and ice and are fed by tributary streams which also originate in lofty regions, so that the water is impounded upon the water-shed in the shape of snow and ice, which serves to feed the river during the period of its lowest flow in the hot and dry months of August and September. The entire water-shed above the falls is high in altitude. Beginning with the top of the falls itself, which is about 600 feet above sea level, it slopes eastward and upward towards the mountain summits where the elevation averages a height of 8000 feet.

The rainfall is about three times that of the district immediately about Puget Sound, where, at Seattle for instance, the rainfall is 37 inches as against about 90 inches at the falls. The meteorological reports show that the annual rainfall increases as the crest of the mountains is approached. The major part of the precipi-

tation occurring in the winter appears as snow, which, melting away in the drier summer months, sustains a very considerable low-water flow.

The company's explorers also noted the fact that the streams tributary to the forks of the main river disappear in the ground in some instances and come to the surface again in perhaps half a mile or more. This physical characteristic of the water-shed in having disappearing rivers sets forth the condition as that of a sponge, holding back in some measure the rainfall only to let it down during the dry season and period of low flow. The area of this water-shed is not over 600 square miles and yet the river at the falls runs from 1000 cubic feet a second at its lowest stage to ten times that at its average stages. A river in the Mississippi Valley would require a water-shed of ten times this area to produce an equal flow, which emphasizes the fact that the Snoqualmie River is remarkable for the amount of its discharge.

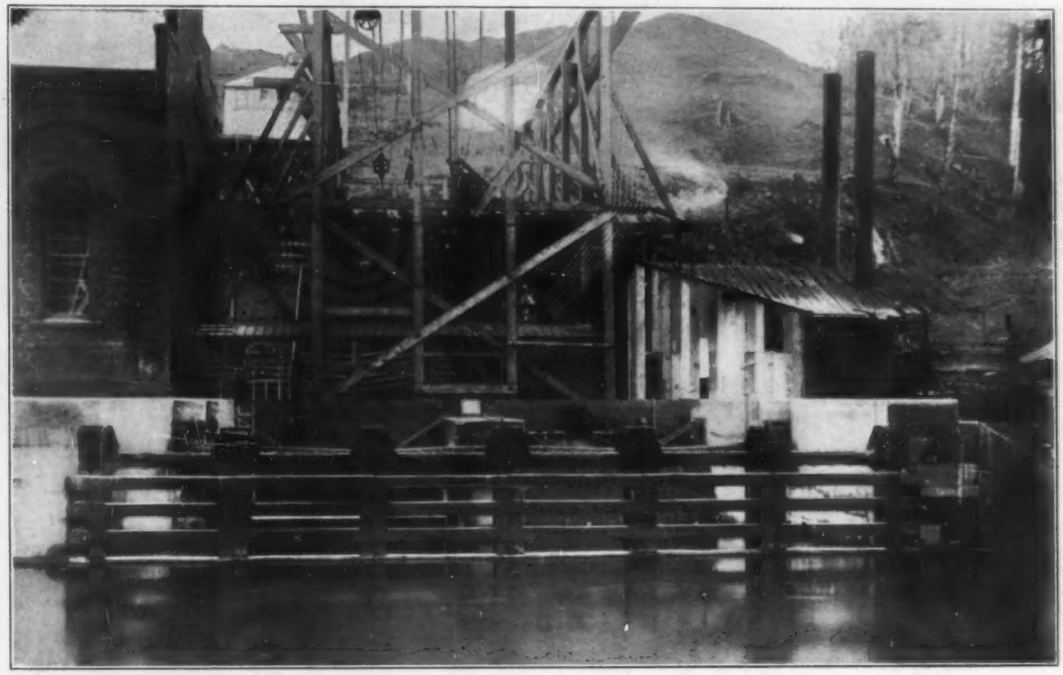
With so much water going to waste the idea is suggested that means might be devised for equalizing the flow of the river and increasing the low-water discharge. This suggestion finds its answer immediately in the researches of the exploring party who have found large lakes and natural reservoirs in the mountains which can be dammed at small cost, so that the water impounded during the flood seasons can be let down during the dry months of August and September. The largest of the lakes are Lake Hancock and Lake Calligan.

Although the water reaches as low a stage at the falls as 30,000 horsepower, the company will be able to secure a uniform flow of 100,000 horsepower throughout the year by the utilization of the numerous natural storage basins referred to. The power could be considerably augmented beyond this figure if at some future time the industries of Seattle and Tacoma and other neighboring cities should require it, by the erection of a dam 50 feet high at the falls. In this way a lake can be impounded behind the falls about 15 miles in area and of an average depth of 25 feet, which, in addition to the mountain storage, would increase the company's ability to develop power throughout the year to perhaps 200,000 horsepower. Probably at some remote geological time, a lake, such as has been suggested, was actually in existence behind Snoqualmie Falls, but it has been drained during the process of years by the wearing away of the rocky river bed and the lowering of the precipice over which the river leaps and forms the cataract. Snoqualmie River does not freeze, so that floating ice and anchor ice are unknown.

One of the first studies was to ascertain the geological formations at the falls as a determining factor in the choice of plans of development, and to ascertain the character and volume of flow. The exposed rock surface in the vicinity, including the railroad cuts, faces of cliffs, and dry river banks, were carefully examined. It developed that a rock uplift, narrow in an east and west direction, extended north and south crossing the river at the site of the falls and disappearing at the east within one-fourth mile. The rock proved to be basaltic and of volcanic origin with no set cleavage, hard and non-absorbent, and apparently seamed off into great individual ledges. These conditions led to the original underground plan of development referred to in the article following by Robert McF. Doble.

A topographical survey, accurate in detail, was made covering a radius of a quarter of a mile from the falls and including the river bottom. At the same time gages were set at convenient intervals above and below the falls, to determine the elevations of the river at the various points at all times, and to establish the slopes at the various levels. These gages have been read three times daily so that the company has an accurate history of the river for the past two years from its own records in addition to less elaborate data for several years preceding from other sources. A clever cut and uniform cross-section of the river is obtained about one-quarter mile above the falls, at which point the company established a station for measuring the velocity of the river at all stages of water. An exhaustive series of accurate measurements has been made here with a current meter.* The river runs pure and crystalline at the falls except in a freshet, when it carries some silt gathered from the valley immediately behind. White clay dissolved in the water is carried by the river at times. Freshets occur generally in November and June, the former due to excessive rainfall prevalent at that season, and the latter to the melting snows in the mountains. The river fluctuates between the high and low water stages throughout the year, with minor freshets interspersed, but the big flood precedes the dry season very closely so that storage for a greater plant would not have to be very long maintained.

A daily record of rainfall, barometer, temperature and all conditions of weather, is kept by the company at Snoqualmie Falls and is reported to the United States Weather Bureau at Seattle.



THE INTAKE, SHOWING REAR OF PRIMARY STATIONS AND TEMPORARY STEAM COMPRESSOR PLANT.

*Compiling the data thus acquired and letting y = elevation of river, x = discharge (cubic feet per second), we find the law of the river to be a parabola with the following equation: $x = \frac{y^2 - 106.8\,y + 2851.6}{.01}$

WASHINGTON'S GREATEST TRANSMISSION.

BY ROBERT McF. DOBLE.

UNQUESTIONABLY the Pacific Coast leads the engineering world in the utilization of natural water powers for driving dynamos to produce electric energy for transmission to distant markets. The building of such "transmissions," as they are termed, is no longer looked upon as an experiment, and the large number of such enterprises in successful operation, both technically and financially, prove their practicability and commercial value and explain why many more and bolder transmissions are under construction or are being undertaken. Of the completed and operating plants one of the most important and interesting is that of the Snoqualmie Falls Power Company, located in the state of Washington.

The Snoqualmie transmission is extremely interesting on account of its several novel features and constructive details, the most notable being the subterannean generating station and the use of aluminum wire for the transmission lines. It is an enterprise of vast proportions and involved much labor and the overcoming of many difficulties in its successful execution; and as for the market, the rapid and substantial growth of the centers of population and commerce to which its power is furnished guarantees a steadily increasing demand for its output, the cheapness and abundance of which is a material aid in still further building up the cities so fortunately situated as to profit by it.

The great fall of the Snoqualmie River is situated about twenty-five miles easterly from Seattle, in the foothills of the Cascade range, on the line of the Seattle and International Railway. With its vertical drop of 270 feet, exceeding the Niagara Falls by more than 100 feet, it has long been famous for its impressive grandeur and the scenic beauties of its surroundings. From a heavily timbered water-shed of above 500 square miles in area on the westerly slope of the Cascade Mountains, and reaching an altitude of over 8000 feet, flow the three principal tributaries of the Snoqualmie River, designated the north, middle and south forks respectively, and which unite about three miles above the falls, forming the river proper.

The water-shed area contains many beautiful mountain lakes and other available sites which may be utilized as storage reservoirs when the present generating plant may have been more than doubled and the demand for power may exceed the natural flow of the river during the summer months. The river has a large low-water flow during the usual dry months, being kept up by the tributaries which reach above the snow line. As to rainfall, that

THE DAM DURING CONSTRUCTION.

on the upper head waters is said to exceed 150 inches per annum, while at the falls the total precipitation is about 90 inches and at Seattle only about 35 inches.

The water of the river usually is pure and clear but carries considerable sand and fine, sharp silt during and after the freshets. These occur generally in November, owing to the heavy rainfall, and during June, owing to the melting snows. The water level fluctuates considerably throughout the year with occasional freshets caused by rain, the minimum flow at the falls being about 1000 cubic feet per second and the maximum over 10,000.

About one-quarter of a mile above the falls, where a uniform cross-section of the river exists, a gaging station was established and an exhaustive series of readings were taken of the height of the river as well as current meter observations. The average velocity obtained was about ten feet per second and a daily record is still being kept of the stage of the river at morning and evening. The river does not freeze during the winter and there is neither floating ice nor anchor ice to be dealt with. The crest of the falls is about 600 feet above the sea level. Below the falls the Snoqualmie River runs almost due north until it makes a junction with the Skykomish River, the two forming the Snohomish River which flows into Puget Sound near the city of Everett.

THE DAM DURING CONSTRUCTION.—SHOWING TROLLEY AND LOADED TRAY.

The rock at the falls is basaltic, with no regular cleavage, is hard and non-absorbent and apparently is divided into great ledges by seams. These conditions led to the adoption of the scheme of placing the entire generating plant in an underground chamber, thus avoiding the necessity of having a long flume or pipe line as is usually required. The location of the power house on the river bank at the base of the falls was considered, but on account of the clouds of spray which keep everything damp and in winter freeze and coat everything with ice, it finally was decided to excavate a chamber in the solid rock.

HYDRAULIC DEVELOPMENT.

The water is taken direct from the river into the intake, a massive concrete and steel construction, about 60 feet along the river. It is built upon the solid rock formation of the river bed, with walls six feet thick and 25

feet high. To keep out floating logs and trees the front of the intake is protected by a timber grating supported by a steel girder frame built into the concrete. The timbers are 12x12 inches laid horizontally with 12-inch spaces between them.

The forebay thus formed is divided into two headbays, separated by a concrete wall six feet thick, both equipped with a massive timber bulkhead and headgate, having an opening 8x12 feet through which the water flows to the penstocks. The headgates are operated by double-screw stems with worm-gear nuts and worm mechanism with large hand-wheels but may also be operated by an electric motor. Only one headbay is in use at present, the other having been provided for doubling the present generating capacity of the plant.

THE DAM AFTER COMPLETION.

The active headbay is further protected by a screen made of flat steel bars on edge which serve to screen out the leaves and other small debris. The timber grating is further protected from floating logs by a floating fender in the form of a rudder boom 300 feet long, which is moored above the intake and extends past it. By turning the capstan at the head of the boom the rudders are thrown out and the boom may be swung into any desired position diagonally across the river. At this point the river is about 150 feet wide and 15 feet deep at low water.

For a distance of about 400 feet up stream and for about 200 feet down stream from the intake, the river banks have been brought to line and protected by massive timber bulkheads constructed of sawed cedar 12x12 inches laid horizontally. The bottom courses are solidly anchored to the bedrock by means of iron bolts, each course being secured to the under one by a liberal number of ¾-inch drift bolts, and every other course being tied back into the solid bank by long 12x12-inch cedar ties solidly anchored. The upper five courses are stepped back eight inches each.

At one place in the upper bulkhead where there was a deep hole under a portion of the bottom timber, steel rails and sheet piling were driven into the stiff clay and securely bolted to the upper structure, and the enclosed area behind the bulkhead was also driven with nests of steel rails and the whole filled with large pieces of rock and tied well back to the solid embankment. Extra precautions were taken with all of the river embankment and intake work as the river is torrential in character and at freshets brings down logs and whole trees of enormous size which would prove disastrous to any construction not of the most massive variety and properly planned to resist such conditions.

For the purpose of raising the low-water elevation of the river at the top of the penstock to a depth of a minimum of eight feet a dam was constructed across the river about 200 feet below the intake and about 200 feet above the crest of the falls. This is a submerged concrete and timber construction about 218 feet between the piers, varying in height from three feet to ten feet, with a level crest eight feet wide, with a slope on the up-stream side of

FROZEN SPRAY AT MOUTH OF TAILRACE.

two to one and on the down-stream side of one-half to one, varying in width on the rock bottom of the river from 16 feet to 35 feet.

At each end of the dam is an abutment pier eight feet square and five feet in height above the crest of the dam. This elevation is also that of the lower bulkhead, which below the dam is continued in the form of a heavy concrete retaining wall, with an outside batter of one-half to one. Thus is formed a spillway over which the water freely flows whenever it exceeds a depth of five feet over the crest of the dam, and allows for the discharge of flood waters without unduly raising the surface of the river above the dam.

To insure a firm bond between the bottom of the dam and the river bed, the rock was laid bare by the use of cofferdams and then roughened up and studded with pieces of steel rails driven into drill holes about two feet deep in the bedrock and also projecting up into the concrete structure from three feet to five feet.

The dam was built during the time of usual low water and work was going on at both ends and in the middle at the same time, the flow of the river being diverted from one place to another, finally being forced through sluiceways which at the last were closed in with timbers and concrete with over a foot of water flowing over the finished portions of the structure.

After the bottom of the river had been made available, a framework and sides were solidly constructed of 6x12-inch timbers, well braced, and this structure was then filled with good Portland concrete and capped over with 6x12-inch timber. The work was handled expeditiously as the stage of the river always is uncertain and twice during the construction the portions completed were completely submerged by freshets. Use was made of an overhead cable one inch in diameter and 500 feet long with a traveler operated by an engine located on the south bank of the river. By this means the timbers, concrete and other materials were rapidly carried to the places desired. The rock was broken by a crusher but the concrete was mixed by hand. Owing to the slope of the banks on both sides of the river the concrete mixing was done on platforms one above another, each process separately, and the ingredients then being passed along to the next through chutes.

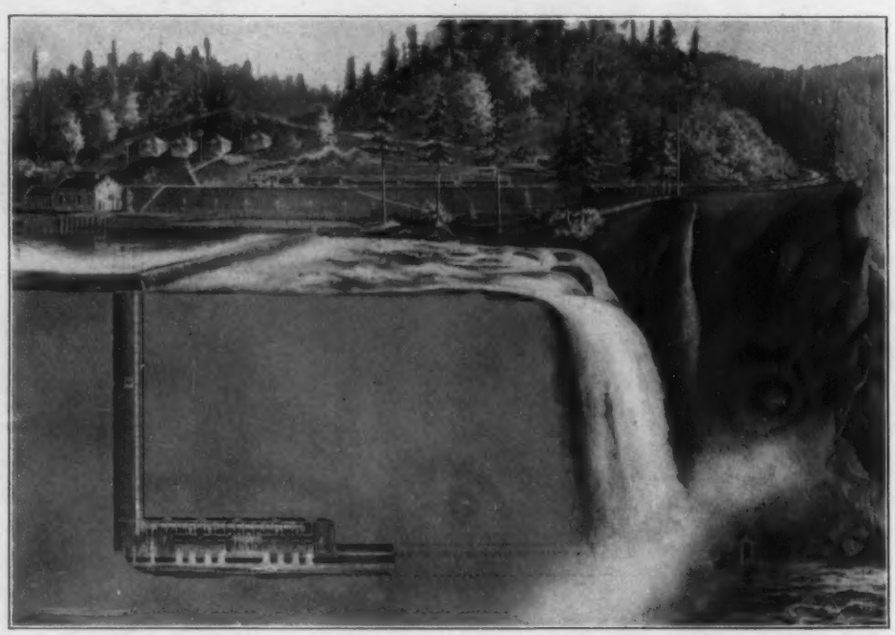
THE SUBTERRANEAN POWER HOUSE.

About 300 feet above the falls, a shaft 10x27 feet was sunk in the bed of the river on the south side, descending 270 feet to the level of the river below the falls. While this shaft was being excavated, a tunnel 12 feet wide and 24 feet high, with a fall of two feet in its entire length, was drifted in from the face of the ledge below the falls, to an intersection with the bottom of the shaft, a distance of 650 feet.

Beginning at the foot of the shaft and extending over and along the tunnel, a chamber 200 feet in length, 40 feet wide and 30 feet high, with the floor at the elevation of high water below the falls, was excavated out of the solid rock. This chamber forms the power house or machinery room in which the water wheels and electric generators have been installed. At average stages of the river the water is about 12 feet deep in the tunnel, while during flood seasons it nearly fills the tunnel. The tunnel extends under the floor of the chamber, forming a tailrace with a concrete roof five feet thick. The walls of the chamber have been left rough and whitewashed, while the floor is covered with concrete.

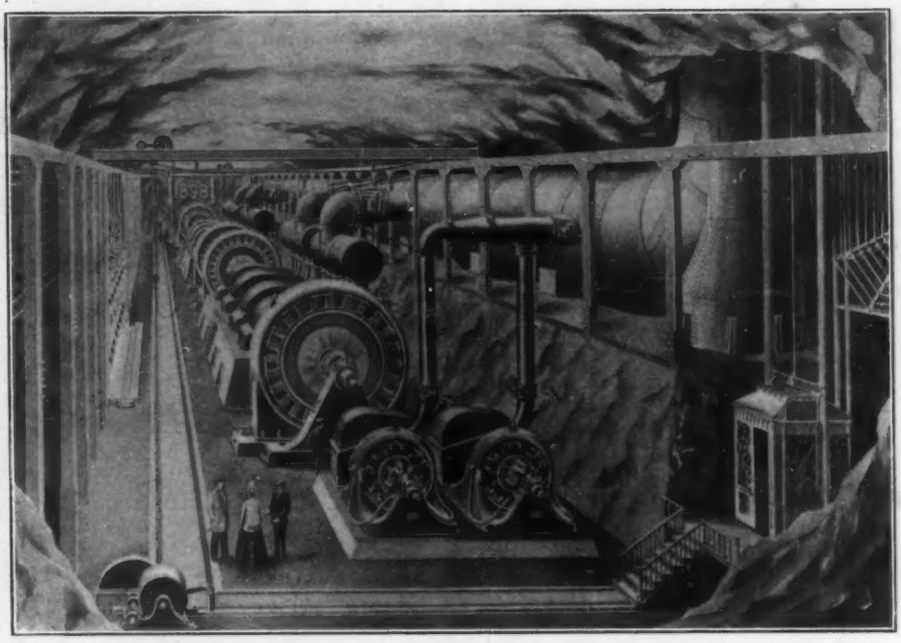
About 700 incandescent lamps are used to light the shaft, chamber and tunnel. The chamber is ventilated by natural draft through the tailrace and up the shaft, the draft being so strong that it has to be curbed. The chamber is cool and perfectly dry, the temperature remaining the same (about 55° F.) throughout the year. This low and uniform temperature contributes to high efficiency of the generators.

The shaft is 10x27 feet, and at the top has three compartments; the two end compartments are for the penstocks, while the center



CROSS-SECTION OF SUBTERRANEAN GENERATING STATION, TAILRACE TUNNEL, FALLS, ETC.

one, enclosed at the top by a steel bulkhead, forms a shaft 8x10 feet for the hydraulic elevator and the main cables forming the outgoing conductors, and also for raising and lowering machinery, etc. The steel bulkhead which encloses this center shaft extends from the bottom of the intake bay to the surface of the ground. It is built up of steel plates, and is stiffened by horizontal frames of I-beams on the outside, riveted to the plates and to each other at the ends. Below it, the elevator shaft is timbered and sheathed with plank. At the surface, this shaft is surmounted by a small building. The penstock already built is a steel pipe 7½ feet in diameter, passing through a concrete roof which keeps the shaft watertight. The plates are in eight-foot courses, and are one inch thick for the lower half of the pipe; in the upper half, the thickness decreases from ⅜-inch to ½-inch at the top. The joints are heavily riveted and caulked watertight. At a depth of 250 feet the penstock reaches the chamber and connects with a horizontal cylindrical receiver which rests on a rock bench in the north side of the chamber, 12 feet above the floor. This receiver extends almost the full length of the chamber. Its diameter is 10 feet for half its length, and then reduces to eight feet. It is built up of one-inch plates, eight feet wide. The penstock and receiver weigh 225 tons, and the weight of the water column in the penstock is 340 tons. A small independent penstock supplies water to the elevator machinery.



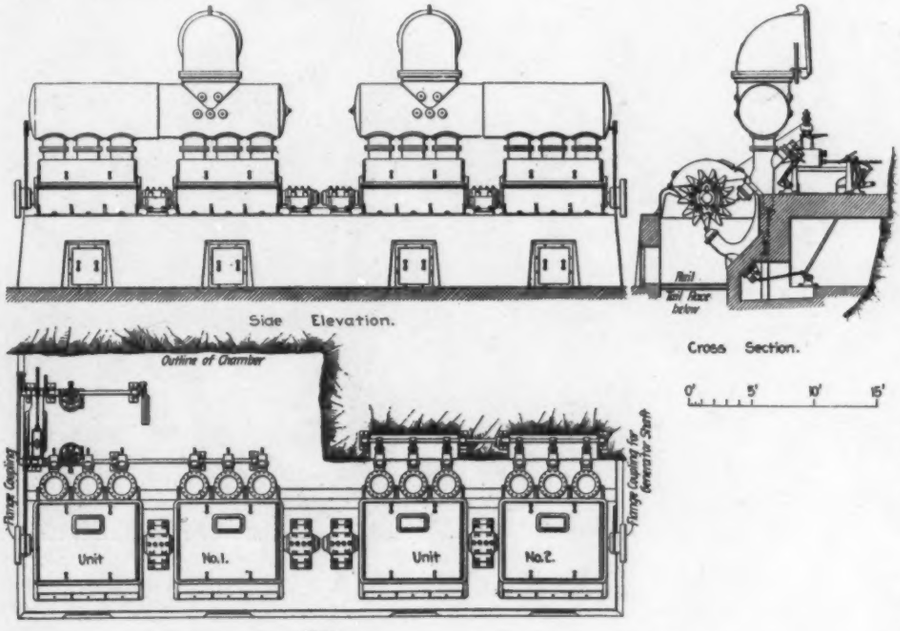
THE UNDERGROUND MACHINERY CHAMBER AS SKETCHED BY AN ARTIST.

THE MAIN HYDRAULIC PLANT.

The hydraulic part of the plant is very interesting, embodying as it does several features that are novel, and designed especially for this plant. The main wheel units are the largest and most powerful tangential wheels thus far attempted under similar head, and the order given for their construction is the largest single order ever given for wheels of their type.

In considering this work in detail, it will be subdivided into two divisions; first, the main power generating wheel sets; second, the auxiliaries consisting of the exciter and elevator operating gear.

In the cavity are installed four wheel units, each developing 2500 horsepower and being direct-connected to its generator. These units are of the tangential ellipsoidal type, as described in detail in THE JOURNAL for October, 1899 (Vol. VIII, p. 85, *et seq**). In considering the units in detail it will be well to follow the course of the water in its passage from the receiver or enlarged horizontal pipe, that is placed on the shelf of basalt, until it is discharged into the tailrace. The several drawings showing the different views of the apparatus will make the written description more easily followed. The following description is of one unit, which applies to all four as they are similar in detail:

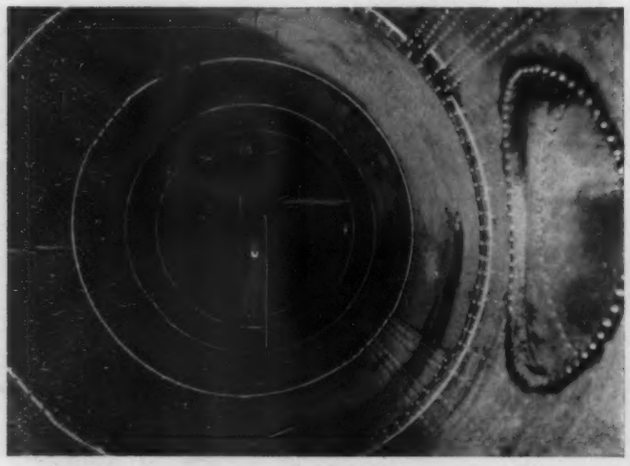


ELEVATION AND SECTION OF WATER MOTORS.

The receiver has four supply openings which are controlled by individual double-screw gate valves of 48 inches inside diameter and weighing 23,000 pounds each. This receiver is horizontal, and the openings are on its side and open towards the cavity. These valves are said to be the largest in the world operated under such pressure. Each is fitted with a small by-pass.

Bolted direct to the gate valve is an elbow casting that directs the water directly downward into the distributing receiver. This elbow is 48 inches inside diameter. The metal is two inches thick and weighs 8000 pounds. Owing to the large diameter of this casting and its form, it required special care in its design to avoid internal strains in the casting that might lead to rupture, especially when considering the high pressure it is required to withstand. The elbow casting was tested to 200 pounds per square inch

*See also Transactions of the American Institute of Mining Engineers, 1899.



INTERIOR OF THE RECEIVER.

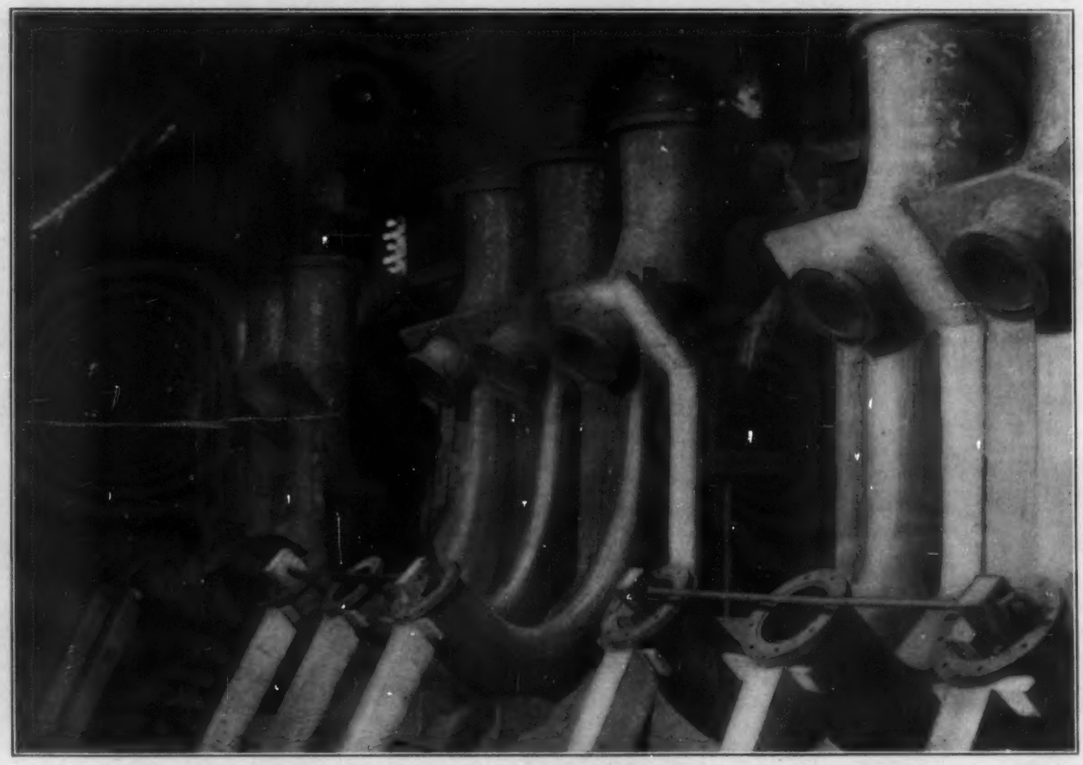
hydrostatic pressure, and test pieces attached to the casting gave over 41,000 pounds per square inch ultimate tensile strength.

The elbow is bolted directly to the flanged opening of the distributing receiver. The water enters the distributing receiver, flowing in a downward direction, and without changing this general direction is discharged from the six openings along the bottom into the six multiple nozzles that direct and regulate the water that is applied to the wheels.

The distributing receiver is 48 inches inside diameter and 20 feet 8 inches in length; is made of tested marine steel plates one-half inch thick, with dished heads. Stay-bolts are used to compensate for the metal removed for the forty-eight-inch opening in the top. The shell is made of two plates ten feet wide, and of a length sufficient to make the shell with only one longitudinal seam, which is double riveted. Flanges and nozzles are cast of semi-steel. By using the distributing receiver to distribute the water to the wheel nozzles simplified the design of the plant, with the minimum of space occupied and with the least disturbances set up in the water, and therefore a minimum friction loss in the water.

The distributing receiver is directly over and is supported by the six regulating nozzles standing upright upon the foundation, and the water is discharged from the distributing receiver without any change in direction, into the nozzles. To make the path of the water as straight and free from any changes in direction as possible, and of a uniform velocity of flow, was carefully considered throughout the entire design. The nozzles stand upright on the foundation, and the extreme or lower end is curved so as to direct the water upward against the wheel; the end of the nozzle terminating in a tip.

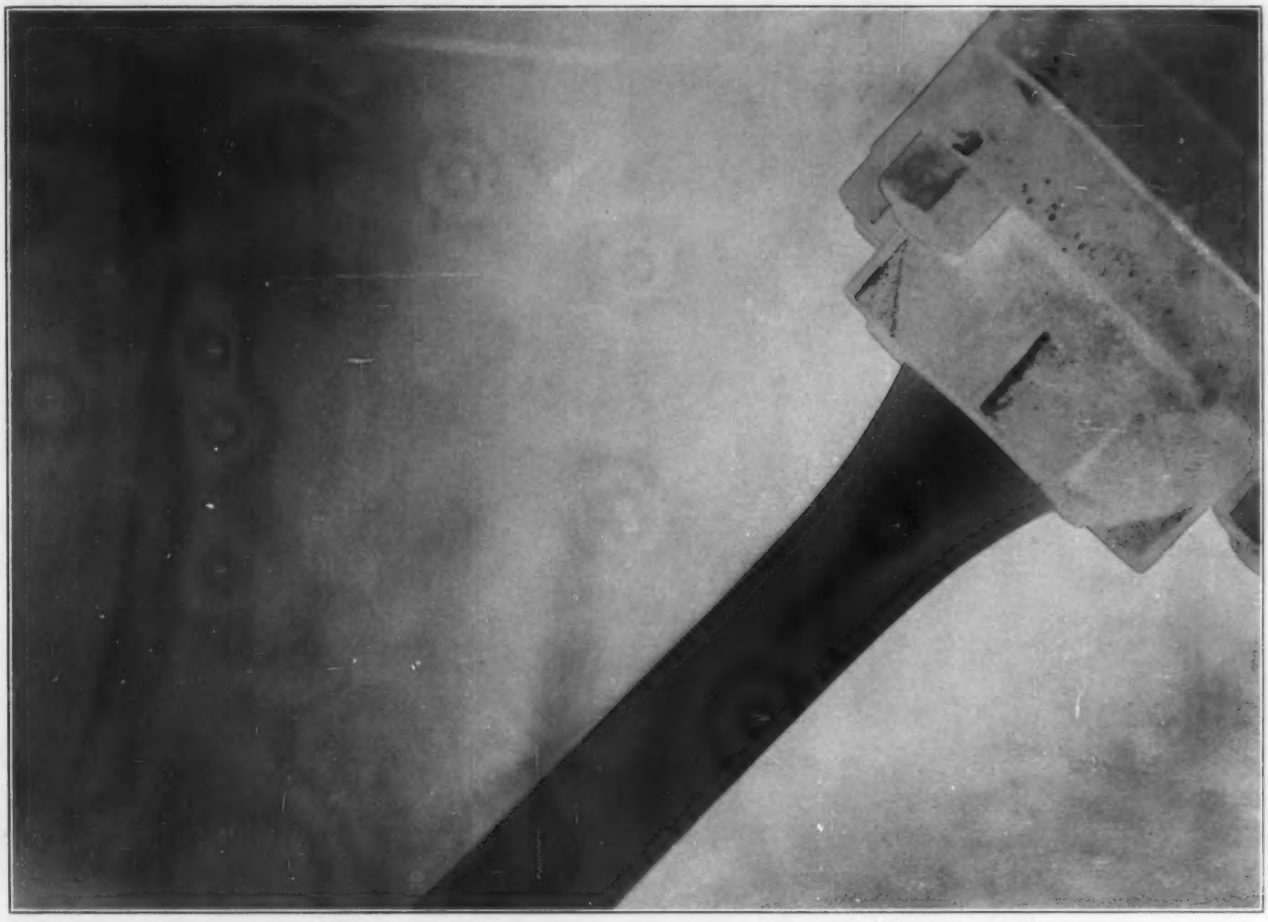
ONE OF THE WATER WHEELS USED ON THE 2500-HORSEPOWER UNITS.



ERECTING NOZZLES AND MANIFOLDS.—UNITS I AND II.

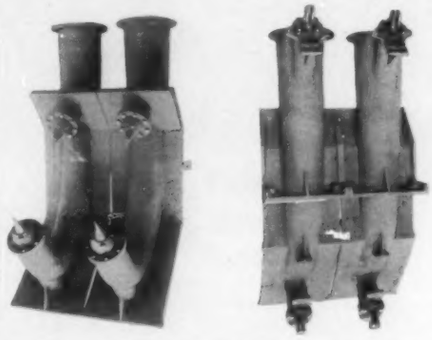
Each nozzle has two tips, each tip discharging a jet of 3⅞ inches in diameter. The first tip is at the upper end of the nozzle and discharges the water in a downward direction against the wheel.

To handle the volume of water necessary to develop the power in each unit under the head of 225 feet, required twelve jets, each 3⅞ inches in diameter, discharging against six wheels. For convenience of bearing and shaft design these wheels were divided into two groups of three wheels each; each group being in a separate housing with a bearing between. This arrangement made two groups of three nozzles each, and as the nozzles were to be in an upright position, for stability each nozzle had wings cast on each side, of the proper length, and flanged so that when these flanges were bolted together it made the nozzles the proper distance apart, and the wings formed the back of the housing or casing in which the wheels revolve, as well as making a most stable construction.



A FLASHLIGHT PHOTOGRAPH OF THE REGULATING NOZZLE AND EXCITER WHEEL IN ACTION.

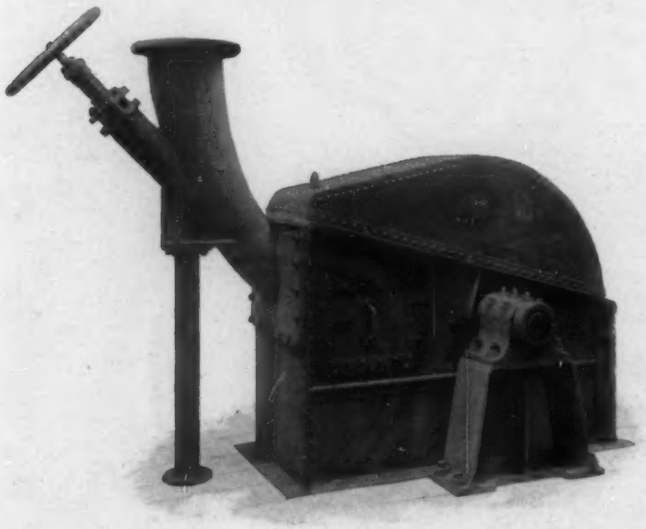
One of the new features of this plant is the regulating tips that are used on the nozzles. They not only throw a perfect and unbroken stream, which can be seen from the above photograph (which is of a three-inch nozzle, 253 feet head, partially closed so as to throw a stream 2¼ inches in diameter), but give an absolute control over the quantity of water applied to the wheels; therefore over the power output of the unit. As the nozzles are controlled by the governor, they give a perfect speed regulation with variable load at a high efficiency, and with the utmost economy in the consumption of water. This photograph is by flashlight, and was taken from one of the exciter wheels at the Snoqualmie plant. It clearly shows a solid, transparent, smooth stream, entirely free from any swirling or other disturbances; in fact an ideal stream condition to deliver the greatest power to the wheels; this form of nozzle maintaining this same condition from full jet to one-tenth of the jet area.



FRONT AND REAR VIEWS OF MAIN NOZZLE CASTINGS.

The regulating nozzles are operated from two long rocker-shafts by means of cranks and connections. One rocker-shaft controls the upper, and the second rocker-shaft controls the lower nozzle tips. Both rocker-shafts are operated by a water-wheel governor which is connected by cranks and connections. The connections to each rocker-shaft are so arranged with clutches that either or both rocker-shafts can be disconnected from the governor and operated or regulated by the hand-wheel on the pedestal stand. By this governor arrangement, with the regulating nozzle tips, the wheels use water in proportion to the power developed, so that the wheels are of very high efficiency at part load as well as at full load. The six wheels have split hubs and solid ribs, and are a press fit on the nine-inch shaft. The wheel hubs are held with four steel bolts 1¼ inches diameter, and the wheels rotate the shaft by means of a steel feather let into the shaft. The wheels are 45 inches in diameter, and are provided with buckets of the ellipsoidal type. The 13 buckets used are attached to the wheel rim by fitted bolts so that the buckets can be replaced when they become worn from scour or otherwise deranged. This is an advantage over wheels of the turbine type where the buckets are part of the wheel casting, and if worn or damaged

require the replacing of the entire wheel. The six wheels are keyed on the shaft in two groups of three wheels each. The shaft is forged steel 9 inches in diameter and 24 feet 5 inches long. On one end of the shaft is a heavy flange coupling which is bolted solid to the coupling on the generator shaft with fitted bolts.



EXCITER WHEEL AND REGULATING NOZZLE—HOUSING CLOSED.

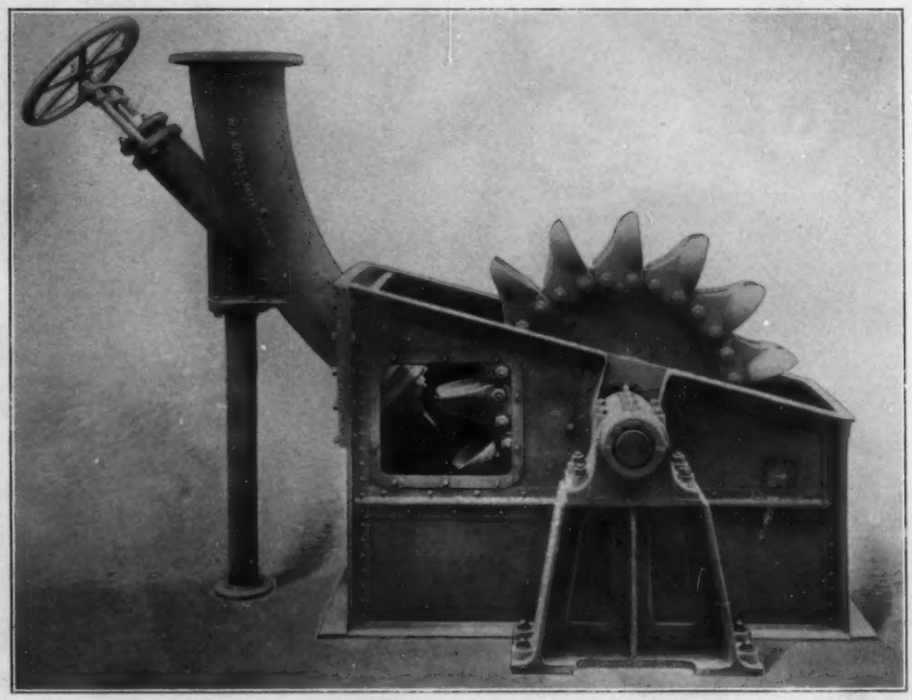
The shaft is supported in two bearings of the ring-oiling, removable shell type. One bearing is at the extreme end of the shaft and the second in the middle of the shaft length and between the two wheel housings. The generator bearing carries the other end of the shaft through the shaft coupling. The bearings are bolted to heavy sole plates that are embedded in the concrete foundation.

The wheels are incased in plate steel housings with cast iron fronts; three wheels in each so that there are two housings to each unit. The housings are made with the upper half removable to provide access to the whole when desired. The cast iron front of each housing is made of such form so as to provide a deflector guard which takes care of the water thrown from the wheels by the centrifugal action, and directs this water into the tailrace, and thus prevents it being driven around the housing by the air currents which are set in motion by the rapidly revolving wheels.

In the top housing is a guarded opening to permit the indraft of air to replace that driven out of the housing and down the tailrace by the rush of the water and the action of the wheels as centrifugal blowers.

Where the shaft passes through the side of the housing, and so as to prevent any water from splashing out, the opening is protected with patented centrifugal disks and guard frames. Although this arrangement prevents the outflow of water, it permits an indraft of air at this point also to replace that driven out by the action of the wheels and the water. This device is entirely free of any mechanical bearings; in fact providing a very large free passage of air. Before this device was brought out, regular packing boxes and glands were used to prevent the exit of water along the shaft, which required to be accurately in line; the packing needed renewing and care; the mechanical bearings required lubrication, and, in all, the packing boxes were a source of continual annoyance and expense, besides setting up some little friction, and, strange as it may seem, no matter how well the boxes were packed they always dripped water, whereas the large free openings of the centrifugal disk and guard are absolutely dry and clean.

As each wheel unit weighs about 100,000 pounds in addition to the weight of water in the distributing receiver and the nozzles, and considering the high rotation of the parts and the power developed, justifies the thoroughness of the design and the construction of the foundations. These are built of concrete and are cemented solidly into the floor and one side wall of the cavity, making an absolutely solid and durable construction; in fact, as durable as the basalt rock in which the cavity is excavated. The tailrace for the discharge water from the wheels is excavated beneath the foundation so that the waste water drops from the wheels into the tailrace and flows out to the river below the falls. The concrete walls are carried up to the proper height so that the heavy sole plates under the bearings are imbedded into the concrete and bring the water wheel bearings in line with the generator bearings. The lower part of the steel wheel housing is firmly built into the concrete walls. The six nozzles standing upright and provided with flanged wings which form the back of the housing, are built in solid with the concrete back wall, making the entire construction of the most solid character. A tunnel is provided under the governor platform for the lower rocker-shaft and connections that operate the lower nozzles, and so as to make this operating gear accessible. The foundation for each unit is divided into two compartments corresponding to the two wheel housings.

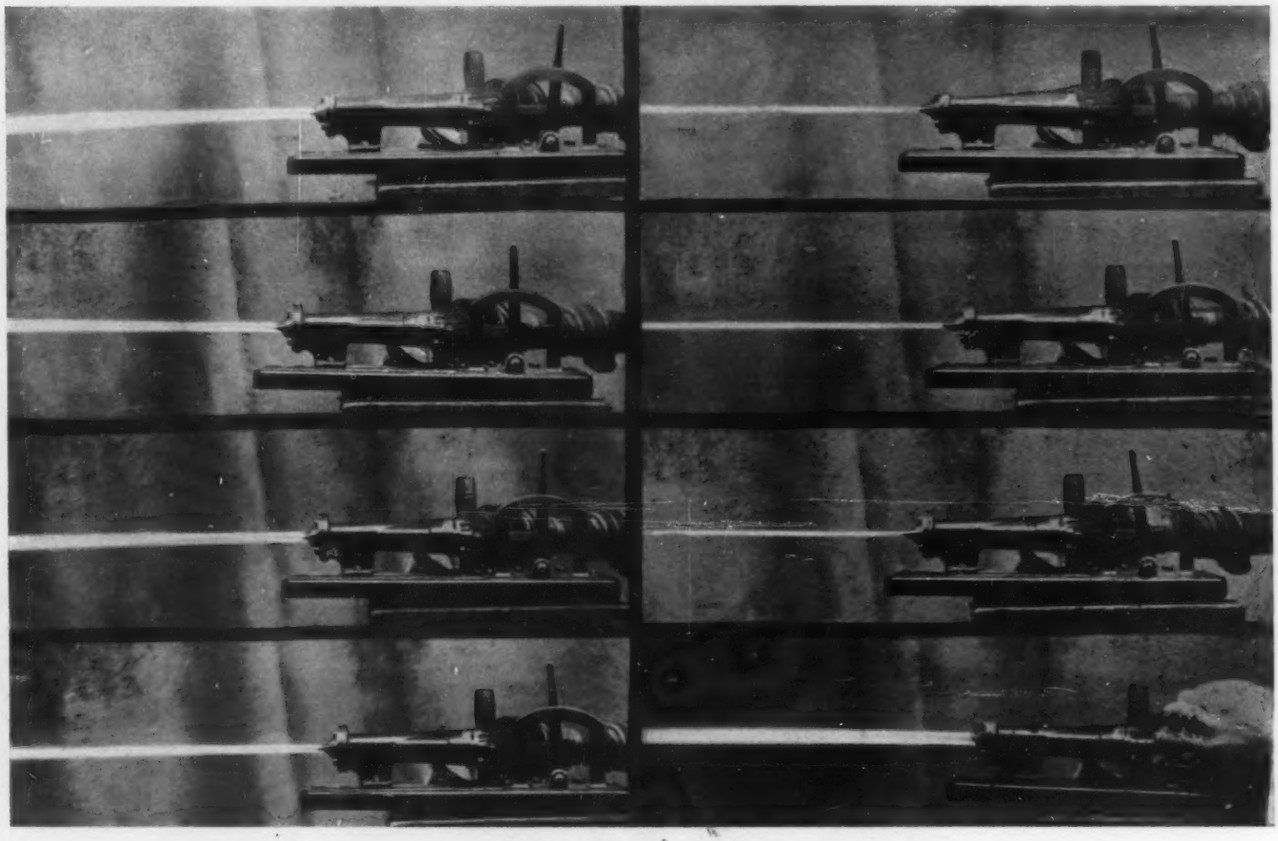


EXCITER WHEEL AND REGULATING NOZZLE—HOUSING OPEN.

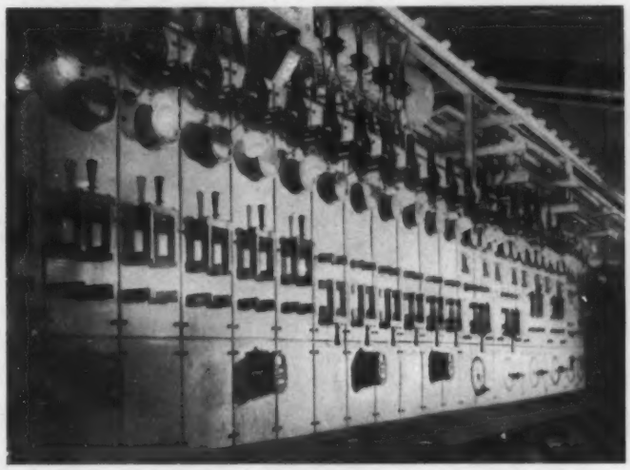
To facilitate entrance a door 2x3 feet is in the front wall of each compartment, and four steel rails are built into the concrete across the opening in the tailrace to support a temporary floor when it is desirable to enter the foundation to inspect the wheels or nozzle tips, without removing the top wheel housing.

AUXILIARY HYDRAULIC APPARATUS.

The exciters are of 75-kilowatt capacity and are direct-connected to tangential ellipsoidal water wheels of 45-inch diameter. The wheels are mounted in steel housings and are supplied with water through a regulating nozzle of three-inch jet diameter. The water is brought to each exciter through a vertical pipe 12 inches in diameter, so that the nozzles are in an upright position. The several photographs and drawings illustrate the arrangement of them very clearly, and the flash-light photograph of the jet of water which was taken with the side plate removed from the housing, shows clearly the perfection of the jet. It is of special interest as the nozzle at the time was throttled so as to discharge a jet of only 2¼ inches diameter. This jet is as smooth and transparent as a bar of glass and entirely free of any swirling or other disturbances, so that it is of the highest value for the development of power; whereas the jets from nozzles of the usual type are in a much disturbed condition and therefore of lesser efficiency.



A STUDY OF THE REGULATING NOZZLE IN ACTION.
(The diameter of the jet varies from ½-inch to ⅜-inch.)



GENERATING SWITCHBOARD IN THE UNDERGROUND STATION.

Another advantage of the regulating nozzle is, should any grass, leaves or other foreign matter become lodged in the nozzle so as to obstruct the flow, by simply opening the nozzle to its full extent all foreign matter is instantly washed out and the nozzle returned to the desired jet diameter. This form of nozzle is of the highest efficiency and maintains this over a wide range of jet areas from full capacity to one-tenth of its capacity. This is of much value as it permits of high efficiency when the wheel is required to develop only a fraction of its rated power, as when part of the generators are not in use at periods of light load.

To make the cavity accessible and convenient for the employees and the handling of supplies, an elevator is provided. This is operated by a winding drum which is driven by a tangential ellipsoidal water wheel seven feet in diameter. The regulating nozzle of 1¾-inch diameter of jet is used for this work as it gives perfect control over the elevator cage.

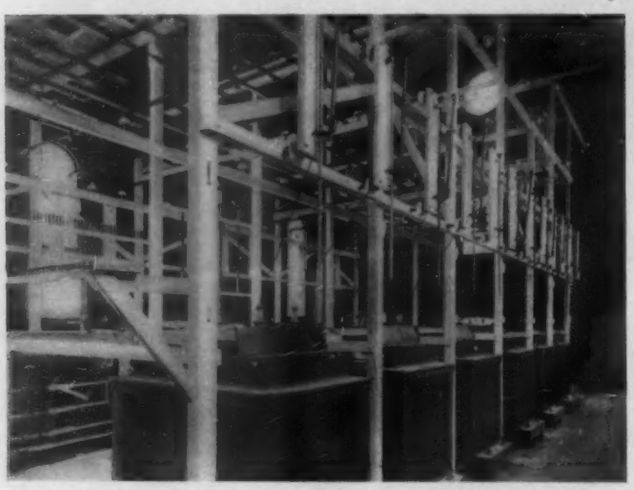
To permit of cleaning the armature of the generators while working, compressed air is available. This is furnished by a vertical type air compressor with an 8x10-inch cylinder.

Traveling the full length of the cavity and covering all of the machinery, are two 10-ton traveling cranes. These were used in installing the machinery and are available to handle the upper wheel housings when it is desirable to inspect the wheels and for such other purposes.

To really appreciate this plant one need only consider that it has a capacity of 10,000 electrical horsepower output, and includ-

EXCAVATING THE TAILRACE TUNNEL.

ing the main receiver and connections, water wheels, generators, traveling cranes, exciter, elevator gear, switchboard and all auxiliary apparatus is in a cavity 40 feet wide, 30 feet high and 200 feet long, every piece of apparatus being conveniently arranged for operation, accessible, and ample room being provided for all purposes; and to realize the ideal simplicity of the plant as an entirety one need only consider that the entire station of 10,000 horsepower output is regularly operated and cared for by two men on a shift,



HIGH-TENSION FUSED SWITCHES. PLUGS FOR MULTIPLE PLUGBOARD, ETC., IN THE PRIMARY STATION.

one an electrician on the switchboard and in charge of the station, standing a watch of eight hours, and the other an oiler serving a twelve-hour watch, whose principal work is one of inspection and keeping the entire station in good order. To better appreciate this, consider the crew required in a steam driven station of equal output with its gang of engineers, oilers, water tenders, firemen, coal passers and its dirt.

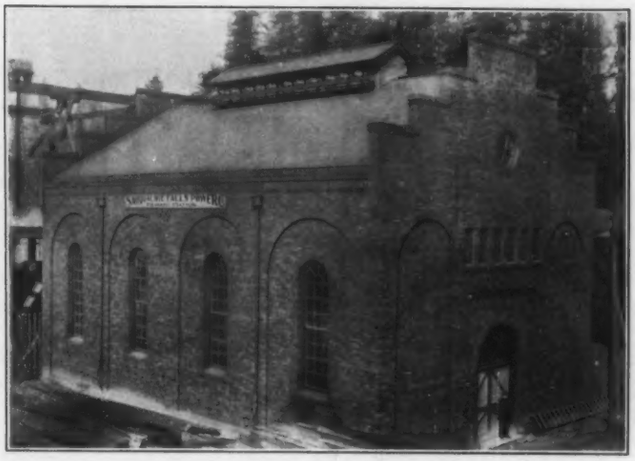
THE GENERATORS.

The generators are of the revolving-armature type and deliver a three-phase current at 1000 volts, 7200 alternations and each weighs about 100,000 pounds and stands 14 feet high. The normal full load current is 1000 amperes per conductor. The armature winding consists of 266 bars with one bar per slot, and is a closed circuit winding. The armatures are 96 inches in diameter and weigh approximately 24,000 pounds each. The speed is 300 revolutions per minute and the peripheral velocity is accordingly nearly a mile and half a minute. Massive collector rings of the ventilated type deliver current to the external circuits. Three brushes bear on each ring, and to insure equal division of current between them in case of unequal contact resistance, separate cable leads of considerable length connect brushes and the outside circuit in order that the fixed resistance with each brush may be

OPENING A 30,000-VOLT CIRCUIT-BREAKER CARRYING LINE-CHARGING CURRENT ONLY.

large compared with the possible variable resistance. The field frame is split vertically and rests on the bed plate which supports the armature bearings. Poles are laminated and cast in the field frame. The field winding is of one-layer copper strap bent cold on edge and afterward insulated. At each end of a coil are brass brackets which rigidly hold it on the pole piece, exposing both inside and outside surfaces to air circulation to carry away heat. This form of construction produces a coil that is very easily insulated, furnishes a maximum surface for ventilation, and at any time may be easily repaired in case of accident. At no load these generators require a field current of 95 amperes at about 90 volts, and with full non-inductive load, 100 amperes to maintain the same electromotive force.

Speed regulation in a water power plant depends greatly on the kinetic energy in the moving parts. In these armatures about 4,500,000 foot-pounds of energy is stored at 300 revolutions per minute, and from the construction of the water motors the moving water column also contributes to the stored energy, since it operates directly upon the revolving parts of the water motor.



STEP-UP TRANSFORMER HOUSE AT HEAD OF THE SHAFT.

The water column in penstock and receiver weighs about 600 tons, and, with one water motor running, has only 67,000 foot-pounds of kinetic energy, or about 1½ per cent. of that in a generator armature. When all the water motors are in operation the water contains much more kinetic energy, but it is still of little importance compared with that stored in the revolving armatures. The stored energy in a single revolving armature is equal to the electrical output of that armature at full load in four seconds.

There are provided two separate 125-volt exciters each of 75 kilowatts and each being more than sufficient in capacity to supply field current to all four of the generators. These exciters are each separately driven by a 100-horsepower wheel, mounted in steel housings. No automatic speed regulators are used here, since the load is perfectly steady, but the regulation of the "needle" valve is effected by hand.

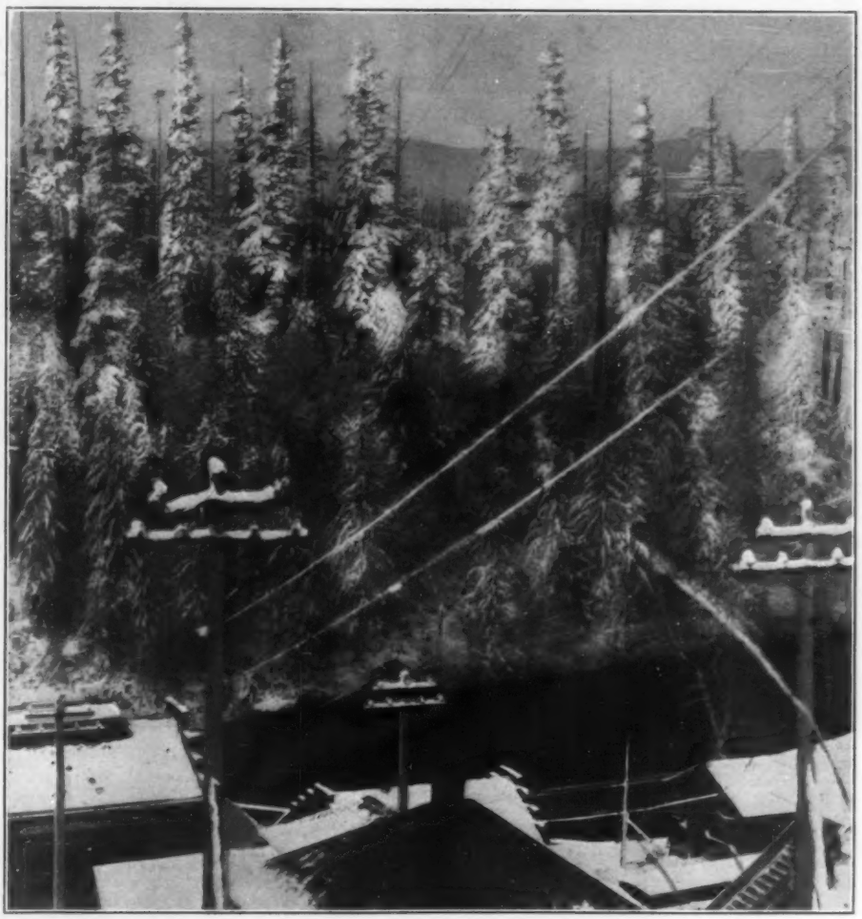
THE GENERATOR SWITCHBOARD.

The switchboard is of white marble, with mountings of brass and bronze. It is 35 feet 5 inches long and 7 feet 6 inches high, and has 18 panels — 4 for the generators, 2 for the exciters and 12 for the feeders. It has two sets of busbars so that different classes of load may be carried separately. Current is conducted by lead-covered cables laid in sewer pipe in the cement floor from the generators to aluminum busbars extending along the south wall to the switchboard. These bars are supported by brackets on glass insulators. They are of pure aluminum, 0.2x3 inches in section and in 30-foot lengths. Three bars carry 1000 amperes with a very moderate rise of temperature. The joints are lapped and bolted, and connection to the switchboard is made by cables with brass terminals which are bolted to the bars. The exciter panels carry ammeters, circuit breakers, ground detectors, voltmeter and plugs and rheostats. Each generator panel has circuit breakers on two of the three phases, synchronizing and pilot lamps, field ammeter, a main ammeter on each of the three circuits, indicating wattmeters of the Niagara type, a field rheostat, double-throw three-pole switches, and voltmeter and ground-detector plugs. The feeder panels have circuit breakers, ammeters and a double-pole double-throw switch, so that each feeder may be put on either the upper or lower busbars. The switchboard also carries three alternating-current voltmeters on swinging brackets, by means of which the voltage in any phase of any generator may be read, connection with the various panels being made through the voltmeters' busbars. The wattmeters are arranged by a simple combination of series and shunt transformers, so that their indication is the same as if they were on a two-phase circuit. This is of considerable value, as the indications of the meters remain equal with a balanced load even if the power factor on the three-phase circuit is less than unity.

To prevent the generators from attaining too high a speed in case of a large amount of power suddenly going off of the system, a water-cooled rheostat is provided. This is in the form of an immersed wire resistance, being composed of spirals of No. 10 B. & S. gage iron wire connected in series of 48 per frame with six frames in multiple per phase, giving about two ohms resistance per phase, and three sets of frames being contained in a tank of running water, delta connection. Three panels are added to the switchboard to serve the rheostat, each panel being equipped with a circuit breaker and a double-pole double-throw switch, so that one or more of the phases may be thrown on the rheostat, or so that it may be used on either the upper or lower busbars.

TRANSFORMERS.

From the feeder panels of the switchboard 24 aluminum cables are provided for conducting the 1000-volt current up the elevator shaft to the transformer house, which stands just east of, and contiguous to, the intake. These cables are bare and are carried on ordinary glass cable insulators supported on timber framework



30,000 VOLTS ON A "COLD" LINE WITH THIS SNOW, AND NO TROUBLE.

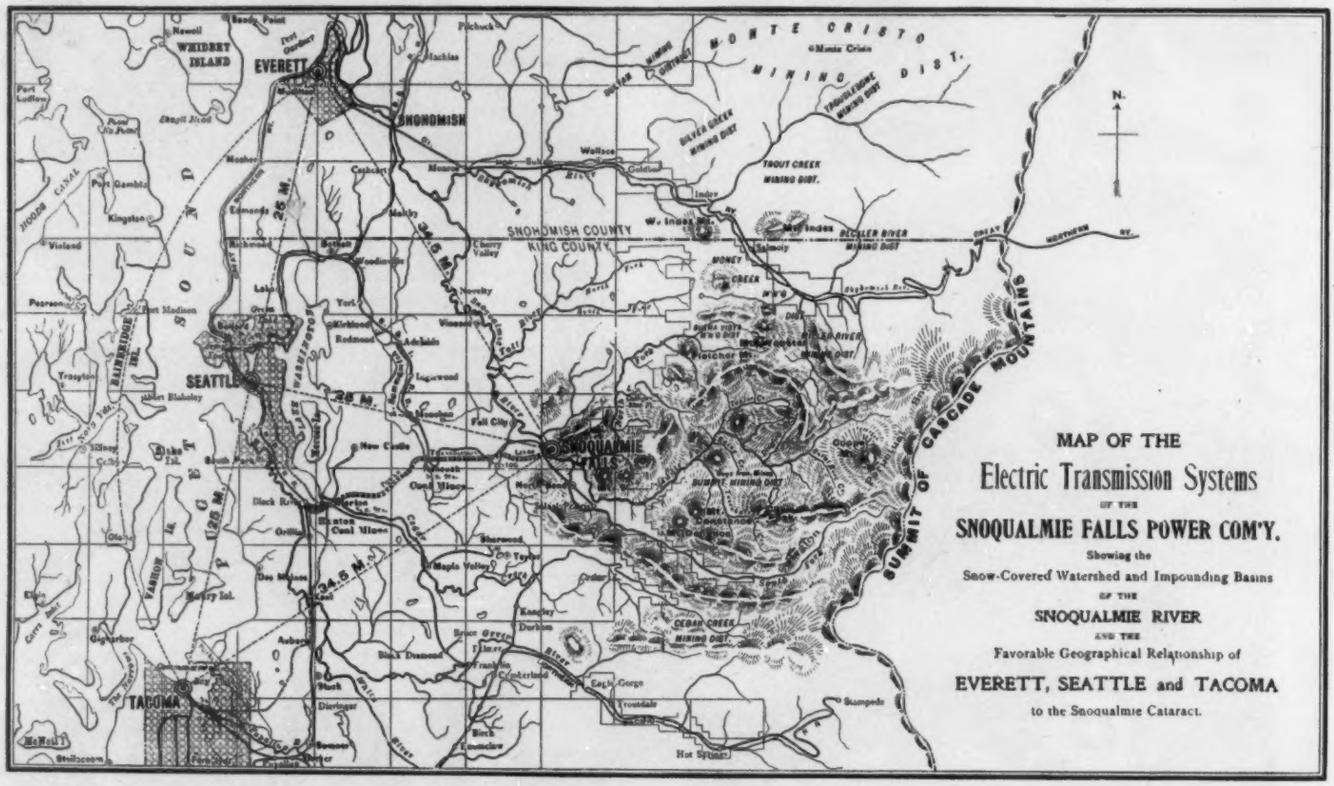
built in the shaft. The transformer house is a fireproof building of brick and iron with concrete floor and slate roof. It is 40 feet by 60 feet and 30 feet high.

There are 12 raising transformers and one extra one for use in case of accident. These are arranged in two rows longitudinally, with an aisle space on each side and a space between for the incoming 1000-volt circuits.

The raising transformers are of the standard Westinghouse self-cooling oil-insulated type, and have a capacity of 550 kilowatts each. Their cases are 55x72 inches and 66 inches high and each contains 500 gallons of oil made specially for transformer use. The experience of the Snoqualmie Falls Power Company with various transformer oils in high-tension transmission service was such that eventually it wisely determined upon the use of only such oil that, upon exhaustive test, should prove itself to be entirely free from acid and all other matters injurious to insulation. The result has been that such a transformer oil is used exclusively in the Snoqualmie transmission system; and it is interesting to note that the total amount of this oil now in use is practically 20,000 gallons.

The primary winding of these raising transformers is for 1000 volts and the secondary winding is convertible for either 15,000 or 30,000 volts. Each complete transformer weighs, approximately, 10,850 pounds, of which 3600 pounds are in iron and copper. These transformers have a very low self-induction. With one of these windings short circuited, less than three per cent. of the normal electromotive force at 7200 alternations per minute will send full load current through the other coil. This is due to subdividing and closely sandwiching the primary and secondary coils, which are thin and flat.

The high-tension coils have many layers with but few turns per layer, and each layer is wound in the same direction, so as to reduce the difference of potential between the successive layers. At the end of each layer the wire is carried across the face of the coil to the starting side. The low-tension coils are of bars or straps wound on edge and afterwards insulated. The coils are spread at the ends outside of the iron core to facilitate oil circulation which carries away heat, and also to increase the distance between the coils where it is difficult to apply solid insulation. Both the primary and secondary circuits of the raising transformers are connected in delta. To protect attendants and apparatus in case of accidental contact between high-tension and low-tension windings, spark gaps are connected between each low-tension winding and the earth. Each transformer is supplied with two high-tension fuse circuit breakers by which it may be disconnected either by hand or automatically in case of excessive current load. The fuse circuit breaker consists of two hinged wooden rods by which the fuse terminals are widely separated, breaking the arc when the fuse is ruptured by the current. The electric arc from this circuit breaker when it operates at 30,000 volts is six feet long. Although it is said that lightning occurs only once in about four or five years, each incoming line wire is protected by a Wurts lightning arrester of improved construction. On the front of a vertical slab, 24x65 inches, are mounted the spark-gap cylinders (in units of seven) in separate porcelain cases, while on the back of the same panel are six choke coils mounted on three marble wings which support the coils and insulate them while they are brought in close inductive action with each other.



An elaborate high-tension plug-board has also been constructed overhead in this transformer house, by the use of which any combination of transformers and circuits can be arranged. The lower (transverse) bars of this plug-board are connected to the raising transformers, and the upper (longitudinal) bars, which are about twenty inches above the lower bars, are connected to the outgoing wires, all connections being through fuse circuit breakers. The connections as desired are made by means of copper plug-rods that are manipulated with a long wooden insulating detachable handle.

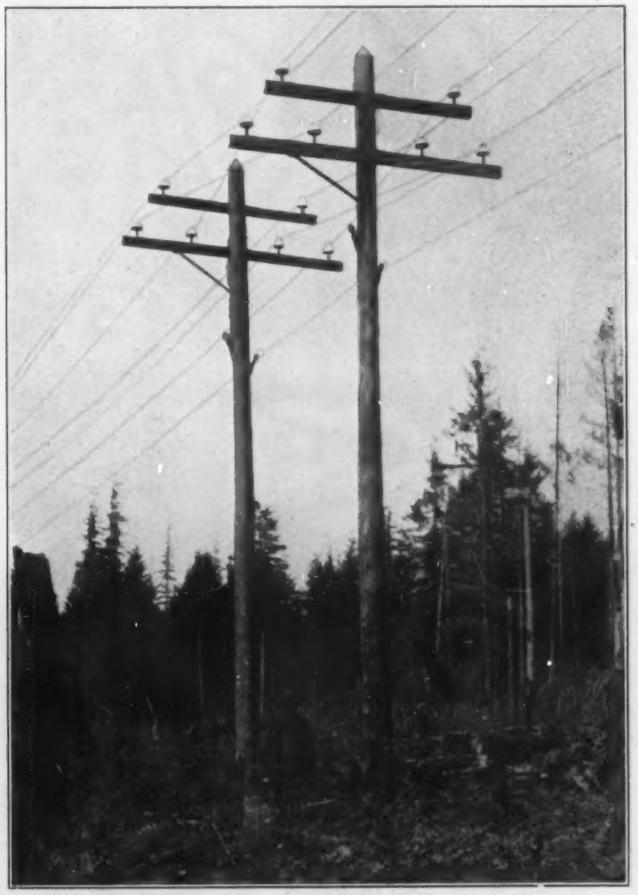
POLE LINES.

The district traversed by the transmission lines varies from mountainous to rolling and flat country. The right of way for the pole line is owned by the company, with the exception of several stretches where the county roads are occupied under a franchise. The right of way is patrolled daily by men on horseback,

each patrolman having a distance of ten miles, and reporting by telephone to Seattle and the Falls from the telephone booths located every three miles. This patrol service has been organized for the purpose of detecting any weakness that may appear in the line and to protect it from any dangers that may threaten. The right of way is, in general, 50 feet wide. In many places, however, the company has a timber right for a distance of 300 feet on each side of the line, with the privilege of felling timber which might injure its operations. This right has been exercised at considerable expense, and trees eight or ten feet in diameter, 300 feet high and 300 feet from the line have been cut, assuming that if they fell they might reach the line and damage it. Now no falling tree can possibly reach the pole lines.

CLEARING THE RIGHT OF WAY.—A CHARACTERISTIC VIEW OF THE COUNTRY THROUGH WHICH THE POLE LINES PASS.

The transmission wires are of aluminum, and in this the Snoqualmie company divides with the Standard Electric Company of California the distinction of being the first to inaugurate the use of this metal in long-distance transmission practice. The conductivity is about 60 per cent. of that of copper, so that the aluminum wire, in order to have a capacity equal to copper, must have a cross-section about 66 per cent. greater, but with this increased size the weight is slightly less than 50 per cent. that of copper.* Longer spans are, therefore, possible, thus making a saving in poles and insulators, and its cost is also less.



A TRANSPOSITION, SHOWING METHOD OF LINE CONSTRUCTION.

The tie wires are of soft No. 8 B. & S. gage aluminum wire, and no electrolysis can occur with these ties, as would be the case with iron or copper wire. The aluminum transmission wires stop at the city limits of Seattle and Tacoma, and copper is used beyond these points for distances of one and a half miles and three-quarters of a mile, respectively. The joints of the line conductors are spliced with a modification of the McIntyre sleeve, which consists of a flattened aluminum tube nine inches long and one-sixteenth of an inch thick, the diameter being sufficient to receive the two line wires. When the joint is made, it is given three complete twists by special clamping tools.

The poles are of cedar, nine inches in diameter at the top, stripped of the bark and either burned or tarred at the butt. The standard length is 36 feet, set six or eight feet in the ground, but the length ranges from 36 to 154 feet, according to the nature of the country. At the crossing of the channel in the harbor of Tacoma there are four poles about 154 feet long, 47 inches in diameter at the butt and 23 inches at the top, weighing 25,000 pounds each. The poles, which were erected with a piledriver, were set in line with a transit and their lengths conform to grades established by the engineers.

The cities of Seattle and Tacoma are reached by separate pole lines. These are parallel and 40 feet apart as far as Renton, 19 miles, where they diverge to their respective terminals: Seattle, 31 miles and Tacoma 44 miles.

The lines are carried on triple-petticoat Imperial porcelain insulators of the Redlands type, 4½ inches high and 6½ inches in diameter, weighing four pounds each. The pins are of locust, boiled in paraffin oil, and carry the insulators four inches clear above the cross-arms. Two circuits are run on each pole line, one on each side, with a triangular spacing of 30 inches between the wires. On the lower cross-arm are four wires, the inner ones 75 inches from the center of the pole and the other ones 25 inches from them; on another cross-arm, 25½ inches above, are two wires, each 40 inches from the center of the pole. The cross-

*The properties of aluminum wires for electrical conductors were exhaustively presented in THE JOURNAL for July, 1899, page 27, *et seq.*—THE EDITOR.

arms are 4½x6 inches, eight and ten feet long. The whole line is substantially built, with poles braced whenever necessary, while double cross-arms are used on all curves and turns and crossings. The length of span on the Seattle line varies from 90 to 150 feet, but the average is 110 feet. On the Tacoma line, the average span is 150 feet. A sag of about 15 inches is allowed, this being con-

THE SUB-STATION AT RENTON.

siderably greater than is common practice with copper wires. The lines are divided into six equal sections on either side of the Renton sub-station by means of transpositions. The spans in which these transpositions are made are between poles set six feet apart, which effectually prevents accidental contact between wires. At each transposition the circuits are given one-third of a turn, always in the same direction.

A telephone line of No. 10 B. & S. gage aluminum wire is carried about five feet below the power circuits on ordinary glass insulators on brackets. It is transposed at every fifth pole. The patrolmen carry portable telephones, so that a call can be made by climbing any pole. Telephone booths, containing also line supplies and tools, are located at intervals of three miles.

SUB-STATIONS.

The first sub-station is at Issaquah (formerly called Gilman), ten miles from the falls. This is a coal mining settlement of about 1200 people. Here a small brick station has been erected from which to distribute current for lighting the town and furnishing power to the coal mines. It contains a Westinghouse oil-insulated air-cooled lowering transformer of 50 kilowatts capacity, and from 30,000 to 2000 volts with variable secondary, the current therefor being taken from one phase of one of the Tacoma circuits. There is a fused high-tension circuit breaker in each of the two wires to the transformer. The station serves also as a residence for the patrolman on this section.

The next sub-station is at Renton, 19 miles, where a brick building 40x40 feet, and 22 feet high, has been erected for the high-tension apparatus and power apparatus, and this also forms the home of the man who has charge of the station and patrols the adjacent section. It contains a 50-kilowatt, 30,000-volt to 2000-volt lowering transformer as in the Issaquah sub-station. The high-tension wires enter the building through marble and glass bushings, and there is a high-tension plug-board, similar to that at the generating station, which admits of making any combination of the incoming and outgoing circuits. Each wire has a high-tension fuse switch. The town has a population of 2000, and is in a farming district. Extensive coal mines in the neighborhood are expected to be eventually operated by electricity furnished from this station.

The terminal sub-station at Seattle is located in the business district. It is a substantial Tenino sandstone building two stories in height. The transformers and other apparatus have been installed in the basement, while the two floors above are occupied by the company's offices.

The 30,000-volt circuits are carried to the building on 70-foot poles, the wires entering a tower on the roof, about 40 feet above the ground, through glass tubes set in marble panels. Thence they are carried through a terra cotta shaft to the lightning arresters which are the same in number and similar in arrangement to those at the raising transformer house at the falls.

On the ground floor are high-tension fuse switches by which the incoming current may be controlled. All of the load may be placed on either transmission circuit, or it may be divided so that the steady load is on one circuit and the fluctuating load on the other, or both circuits may be connected in multiple. The switching apparatus is of extreme flexibility. There are also high-tension fuse switches for the lowering transformers located in the basement.

There are at present three step-down static transformers with primaries and secondaries in delta connection, for supplying 350-volt current to the 500-volt rotary transformers. The primary coils may be connected either for 12,500 volts or 25,000 volts. The secondary coils have intermediate terminals by which the electromotive force supplied to the rotaries may be adjusted when necessary. Otherwise the transformers are similar in construction and capacity to those of the generating station. There are also four pairs of two-phase to three-phase lowering transformers of 300 kilowatts capacity each, and two pairs of 500 kilowatts each, with 2000-volt secondaries for general lighting and power distribution, which makes the total station transformer capacity 3700 kilowatts. These transformers are equipped with potential regu-

THE SUB-STATION AT GILMAN.

lators by means of which the secondary voltage may be changed to suit the conditions of variable loads.

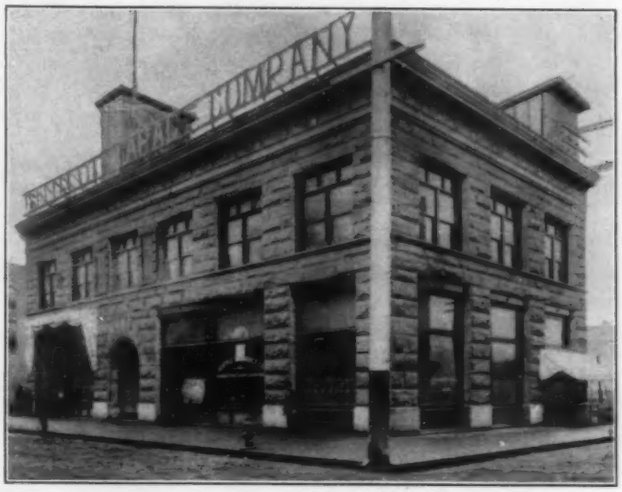
White marble switchboards are furnished for controlling the three rotary transformers. Each of the alternating-current panels contains a three-pole single-throw washer switch, three ammeters,

synchronizing lamps, field rheostat and a switch for the starting motor on the rotary. On each direct-current panel are a circuit breaker, ammeter, voltmeter, plug receptacles, and two single-pole washer switches. The feeder panels have circuit breakers, single-pole washer switches and Thomson recording wattmeters. Voltmeters are mounted at the end of the board on a swinging arm.

There are two rotary transformers of 500 kilowatts capacity delivering current at 550 volts, which are operated in multiple on both alternating and direct current sides. A third rotary of equal output has been ordered. These rotary transformers have 18 poles and run at a speed of 400 revolutions per minute. Collector rings and brushes are like those on the generators but of smaller capacity. To bring the rotaries in synchronism without excessive starting current, a small induction motor is mounted on the armature shaft. As this has 16 poles, it is enabled to bring the rotary armature slightly above synchronism.*

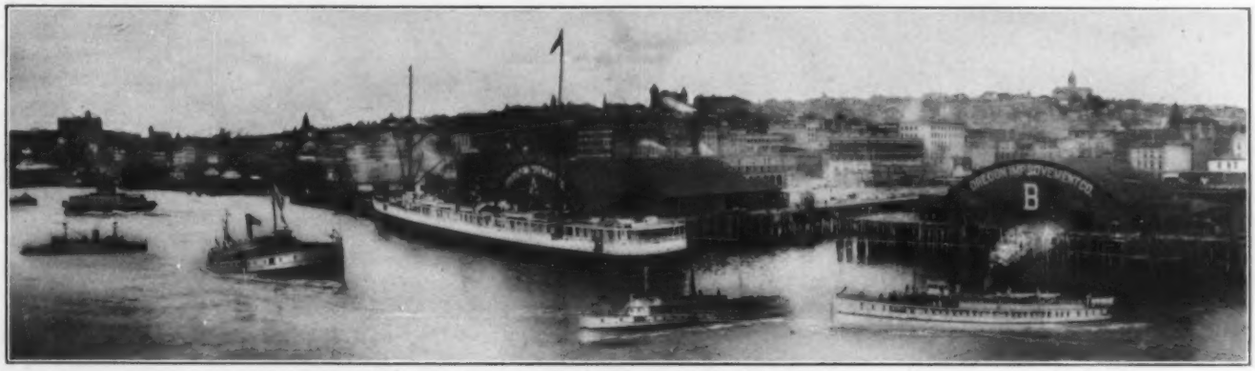
For alternating-current lighting and power-motor work, a panel is provided for each set of three-phase, two-phase transformers, containing two 2000-volt automatic circuit breakers, two ammeters, two Niagara-type indicating wattmeters, two double-pole throw switches and pilot lamps. The feeder panels are the same, except that polyphase integrating wattmeters of the Westinghouse type are used instead of the indicating wattmeters. In making changes on these boards the circuits are first opened by the circuit breakers as the switches are not designed to break current.

The Tacoma circuits pass through Auburn and Kent, each having a population of about 1000, and being in a farming and dairy district. A small sub-station has already been established at Auburn, 31 miles from the falls, and another is to be established at Kent, 25 miles. The former place is on the Northern Pacific Railway, where its lines from Seattle and Tacoma meet the main overland line. The Auburn sub-station contains a 50-kilowatt lowering transformer the same as used at Issaquah.

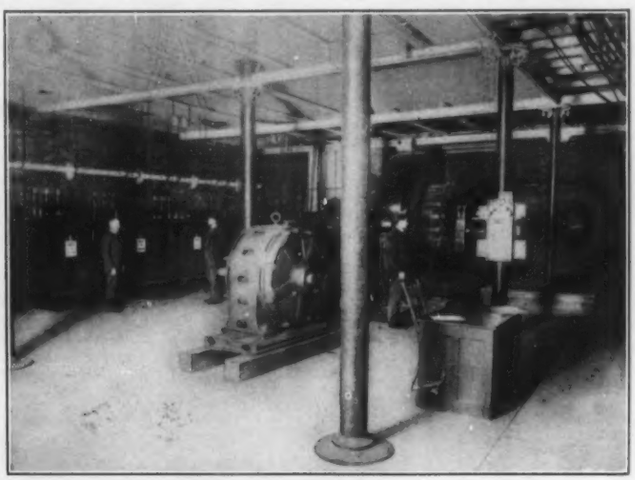


THE SNOQUALMIE BUILDING, SEATTLE.—OFFICE AND SUB-STATION.

The terminal sub-station at Tacoma is a red brick structure, occupied jointly with the Tacoma Railway and Power Company.



THE CITY OF SEATTLE.



A CORNER IN THE SEATTLE SUB-STATION.

The line circuits are equipped with high-tension fuse switches as at Seattle, by means of which the transformers may be connected to either circuit or in multiple.

The Tacoma station is equipped with three 500-kilowatt transformers and two 200-kilowatt transformers, similar in type and style to those at Seattle, making 2100 kilowatts total capacity at Tacoma. These transformers are also equipped with the potential regulators on the secondaries of the transformers as at Seattle.

To take the place of steam engines and in order to utilize Snoqualmie electric power, the Tacoma Railway and Power Company has installed a 1000-kilowatt, two-phase, 2200-volt General Electric synchronous motor of the revolving field type. This is used to drive a long jack-shaft having a diameter of nine inches and from which are belted a number of railway generators and series-arc machines.

The Tacoma company also has a 100-horsepower, 2200-volt General Electric induction motor which drives the rope drum of the cable railway system of Tacoma. In addition there are two 750-horsepower General Electric motor-generator sets, each consisting of a 2200-volt induction motor and a railway generator mounted on the same base-plate, the armatures on the same shaft and the field frames close together. A very complete switchboard is provided for these motors as well as for the railway feeders and for the 2000-volt distribution about the city.

Vide THE JOURNAL, Vol. VI, page 98, for information concerning rotaries. —THE EDITOR.

TESTS ON THE 153-MILE LINE.

By the use of the plug switching boards at the generating station and at the Renton sub-station, and of the paralleling switches at the Seattle and Tacoma sub-stations, it is possible to form a single continuous three-phase circuit from the generating station at the falls to Seattle, back to the falls, to Tacoma and back to the falls—a total distance of 153 miles. Such a line would be constituted as follows:

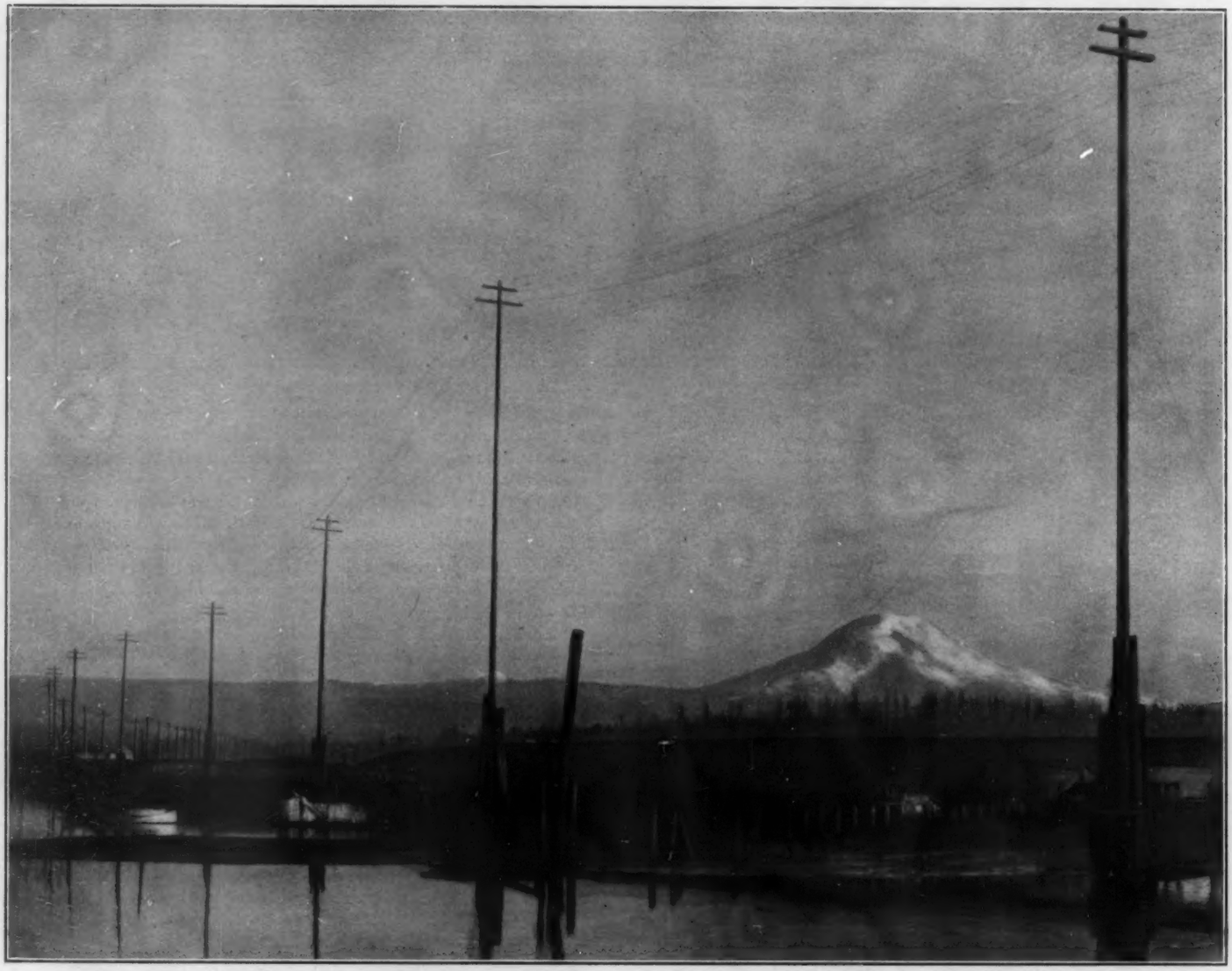
Aluminum, 264 mils		58.00	miles,	solid
Copper,	No. 1, B. & S. gage	4.00	"	"
Aluminum, 234 mils		51.00	"	"
"	No. 2, B. & S. gage	36.66	"	cable
Copper,	No. 2, B. & S. gage	1.66	"	solid
"	No. 0	1.66	"	"
Total		152.98		

For several hours during the daytime of November 18th last, the various distributing services of the company were cut off and the transmission circuits were connected up as one in the manner above indicated, and the record feat of driving a motor 153 miles distant from the generator was performed.

Before making the transmission tests the circuit to Seattle and back, 62 miles, was tested, and the ohmic resistance was found to be 86 ohms; likewise the Tacoma circuit of 91 miles was found to be 152 ohms, the complete circuit of 153 miles giving 241 ohms. Current from the exciter was used for making this test, the resistance to ground being 700,000 ohms.

The long-distance transmission tests were conducted for experimental purposes only, and to show that electrical transmission of power can be made commercially practical at much greater distances than has heretofore been contemplated. One of the Westinghouse 1500-kilowatt, three-phase generators furnished the current, and a similar machine was used as a synchronous motor at the end of the circuit. A bank of the raising transformers was used as lowering transformers and one of the feeder circuits was used to convey the current down into the generator chamber to the switchboard. Only the regular switchboard instruments were used for the readings. Where kilowatts are given they are the sum of the wattmeters and are not kilo-volt-amperes.

With the 153-mile circuit open at the incoming end, the tests were made for charging them at different voltages, the alternations (7200) being kept constant. It was found that as the voltage increased, the charging current rapidly increased; at 22,500 line voltage it required 62 kilowatts to charge the line, at 30,000 volts it required 112 kilowatts, and at 35,000 volts it required 180 kilowatts. With the lowering transformers at the falls cut in and their secondaries open, it was found that the current required to charge the line increased; at 22,500 volts it required 76 kilowatts, and at 30,000 volts it required 123 kilowatts. The voltage at the incom-



154-FOOT POLES ON THE LINE ENTERING TACOMA.—MOUNT RAINIER IN THE DISTANCE.

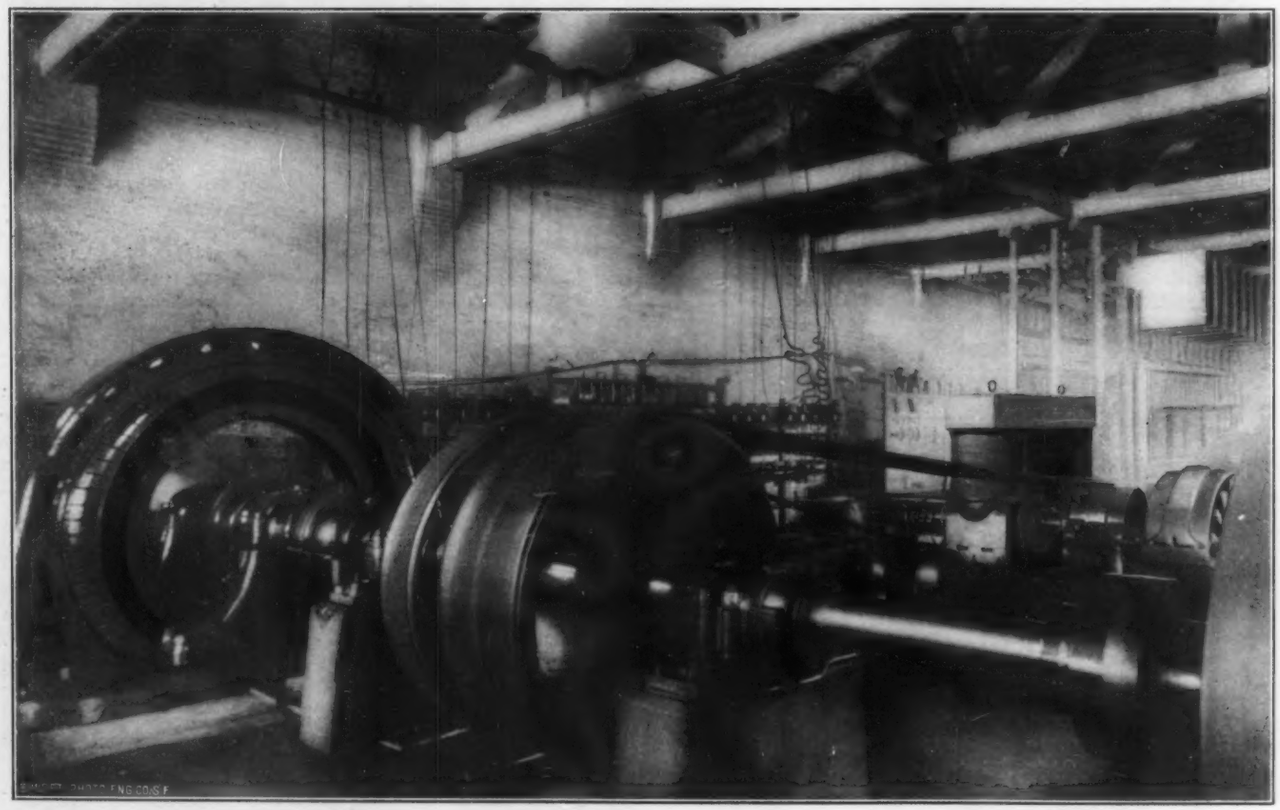
THE CITY OF TACOMA.

ing end of the circuit, with charging current only on the line, was greater than at the outgoing; 22,500 volts out, gave 24,600 in, and 30,000 volts out gave 32,100 in. Tests were also made to determine the different amount of charging current required at different frequencies, the voltage being kept constant at 30,000, and it was found that at 6000 alternations 100 kilowatts were required to charge the line; at 6600 alternations, 105 kilowatts; and at 7800 alternations, 115 kilowatts.

The line was then tested for loss of power in transmitting a non-inductive load, consisting of the water rheostat at the falls at the end of the 153-mile circuit. It was found that the line voltage out was 30,000, incoming 22,500, drop 25 per cent. The amperes per phase at 1000 volts out was 624, incoming 354, loss 11.2 per cent. The total kilowatt outgoing was 1100, incoming (that is delivered into the water rheostat tanks) 723, loss 34.2 per cent.

A test was also made for charging current with the sub-station transformers at Seattle and Tacoma, and the lowering transformers at the falls in circuit, but with secondaries all open, and it was found that with the 30,000 volts out, there was 31,500 volts in, and that it required 193 kilowatts to charge the line. A test was then made of operating a second generator as a synchronous motor at the end of the circuit and the machines were synchronized without any trouble whatever; but they soon began pumping so that it was found advisable to separate the machines. During this test the outgoing line voltage had varied from 26,700 to 27,600 and the incoming from 24,000 to 26,700, giving approximately a drop of six per cent., the amperes per phase at 1000 volts out being approximately 900; incoming, approximately, 650; loss, approximately, 27.7 per cent. Total kilowatts out, 432; incoming, 374; loss, approximately, 13½ per cent. The figures on this last test are approximate only, as all of the instrument needles oscillated very much, many of the ammeters fluctuating over the entire range of the scale. The foregoing losses would be greater or less according as the loads carried might be increased or diminished.

The experiment was then tried of operating the water rheostat and the synchronous motor in multiple at the end of the 153-mile circuit and the performance of the motor was very much improved. The water was then shut off from the water wheel and the driven motor at once reverted to a generator driven by its own inertia.



A 1000-HORSEPOWER SYNCHRONOUS MOTOR DRIVING THE TACOMA RAILWAY COMPANY'S ELECTRIC POWER HOUSE.

MARKETS FOR SNOQUALMIE POWER.

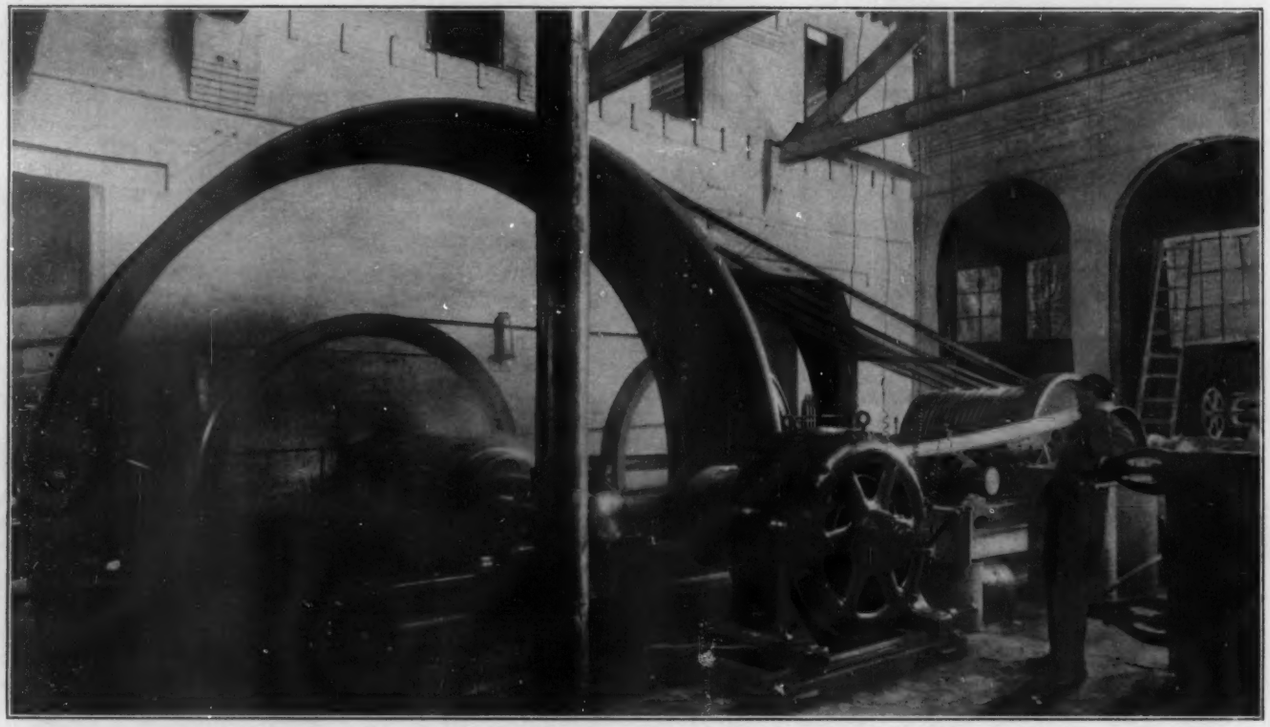
The Snoqualmie Falls Power Company furnishes power for both lighting, railway and general power purposes, and it is expected that many of the manufacturing plants of Seattle and Tacoma will soon be operated by the power from Snoqualmie Falls. The power in Issaquah, Renton and Auburn is used for lighting purposes only, for both incandescent and arc lights. In Seattle, all the stationary motors are being operated, and the entire municipal street lighting system; also the Centennial flour mill, 2000 barrels daily capacity, the Capital flour mill, 300 barrels daily capacity, and about half the street railways. All the street railways will soon be operated from this service. In Tacoma, the municipality owns the lighting system and power is purchased for the purpose of running it. The Snoqualmie power is furnishing nearly all the lighting circuits in Tacoma at present, and the others are to be added as soon as the transformers have been changed to adapt their distribution to the frequency of this plant. All the electric roads are under contract and will take the current as soon as the induction motors which are to drive a line shaft have been installed. An induction motor is also employed at Tacoma in a grain elevator for loading ships.

The manufacturing plants in Seattle and Tacoma include three flour mills, a smelter, car shops, several iron works, elevators, machine shops, etc. The operation of the municidal water works pumping station for Tacoma is also contemplated. Negotiations are also in progress for the establishment of electrolytic and chemical works. Almost the entire output of power was contracted for before the Snoqualmie Falls power plant was in operation. The first customer was the Centennial Flour Mill Company, of Seattle, which contracted for power nearly a year before the completion of the plant. All the machinery for operating the mill, including that for grinding, cleaning, ventilating, receiving and delivering the grain and flour by elevators, etc., is operated by two Westinghouse motors of 200-horsepower each, which have entirely supplanted the steam power equipment. A third 200-horsepower motor has been ordered, so that the capacity of the mill may be increased.

The city of Seattle has a population of 80,600; Tacoma, 38,500, and Everett, 10,000. These three cities and the neighboring towns are rapidly growing and increasing in industrial importance, and many small industries and factories, large in the aggregate, are being established. The Snoqualmie Falls Power Company does not engage in the distribution of power to small customers, but sells power in large blocks for this purpose to the Seattle Cataract Company and the Seattle Electric Company, in Seattle, and the Tacoma Cataract Company and the Tacoma Railway and Power Company, in Tacoma. It reserves for itself the duty of supplying large plants of every description which can be reached by any of its lines or extensions. A transmission line to Everett is proposed, 35 miles from the falls, where a paper-mill, smelter and other industries in operation would take 2000 horsepower. The company's policy is to build up a business of large volume at moderate prices, rather than small volume at high prices.

The waterfall and the land on either side were purchased in the autumn of 1897 by Wm. T. Baker, of Chicago, who organized the Snoqualmie Falls Power Company early in 1898. Work was commenced as soon as the organization of the company had been perfected. The construction plant included two 125-horsepower boilers, an air compressor delivering air at 100 pounds pressure into a receiver 4½ feet diameter and 12 feet high, 10 rock drills working under 60 pounds pressure, and a sinking pump with a five-inch suction and four-inch discharge to keep the shaft excavation dry. Owing to the solid character of the rock, however, very little water entered the excavation. It was surrounded by a cofferdam 15 feet high to prevent flooding in case of high water in the river. Over the shaft was a hoisting trestle 50 feet high, for the cages, which were operated by a 75-horsepower double friction drum engine, which could raise a load of 6500 pounds at a speed of 450 feet per minute. The rock dumped at the trestle was carried by a gravity tramway to a crusher with a capacity of 70 cubic yards. This was driven by a 15-horsepower engine, and crushed stone was piled up for future use in the concrete work. All the concrete was mixed by hand.

To supply air to the drills in the tunnel, a pipe line was extended 400 feet to the edge of the cliff, and a section of pipe lowered to the bottom, a depth of nearly 300 feet. Two men suspended by



A 100-HORSEPOWER INDUCTION MOTOR DRIVING THE TACOMA CABLE RAILWAY SYSTEM.

ropes, and working in the whirling spray and wind of the chasm, put the pipe lengths together, building it up from the bottom and constructing the necessary timbering to support it against the rough face of the cliff. At first, all tools and material had to be carried up and down a winding stairway, but a standing cable was soon put in place, on which ran a box for tools, operated by means of a windlass.

For handling heavy material, a trestle was built over the side-track and extending to the shaft; upon this was a traversing hoist, by which the material was raised from the cars and carried to the works. The first drill was set in operation on April 17, 1898, and the work was then prosecuted by day and night until completion. The first water wheel and generator in actual operation delivered current into Seattle July 31, 1899, and into Tacoma, November 1, 1899. A number of features yet remained to be completed, so that the plant has only recently been fully installed. The finished enterprise will represent an investment of about $1,000,000.

A substantial brick building, 34x50 feet, with slate roof, has been erected near the transformer house for use as a repair shop, with separate rooms for the machine shop, carpenter shop and blacksmith shop. The machine shop contains a 12-foot, 20-inch lathe, a 28-inch drill press and a 24-inch shaper. This building also contains the company's headworks office and a storeroom. About 27 acres of ground covering the works, the brink of the falls and both banks of the river have been laid out as a park, with lawns, walks and flower beds, the grounds being illuminated by arc lamps. Comfortable cottages and a dormitory, with all modern conveniences, have been erected by the company, and there is also a cottage for the executive officers and for visitors.

PERSONAL.

Of this company, Charles H. Baker is president and general manager, and the other officers are as follows: vice-president, A. H. Andrews; secretary and treasurer, George G. Lyon; manager at Tacoma, James C. Drake. The company has its main offices at Seattle, Wash., and a branch office at Tacoma, Wash. Thomas T. Johnston, consulting engineer of the Chicago Drainage Canal, was consulting engineer during the construction of the works, and James J. Reynolds was the superintendent of construction. The electrical engineer was E. M. Tingley and Robert McF. Doble was mechanical engineer and superintendent during the installation of the water wheels and final completion of the plant. The construction work was done by the company and not by contract.

WILLIAM T. BAKER.

Of these, the interest of the public centers in Wm. T. Baker, who is the organizer and sole owner of the Snoqualmie Falls Power Company, and in his son, Charles H. Baker, under whose general management the work has been carried through to its present successful outcome. To them more than passing reference should be made.

William T. Baker was born in Winfield, Herkemer county, New York, September 11, 1842. His early education was confined to the country school and ceased at

DATA OF THE HYDRAULIC AND ELECTRICAL EQUIPMENT OF THE SNOQUALMIE FALLS POWER COMPANY.

WATER DEVELOPMENT.

Catchment area: 600 square miles.
Maximum flow of river: 160,000 cubic foot seconds.
Minimum flow of river: 10,000 cubic foot seconds.
Height of Snoqualmie Falls: 267 feet.
Effective head: 253 feet.
Estimated energy available: 100,000 hp.
Average annual precipitation: 90 inches.

HYDRAULIC EQUIPMENT.

Penstock and Receiver. Length: 250 feet.
Position: vertical.
Diameter: 7½ feet.
Material: steel, 1 inch, ⅞ inch and ½ inch in thickness.
Receiver. Length: 185 feet.
Position: horizontal.
Diameter: 10 feet for half its length, 8 feet for remainder.
Material: 1-inch steel plates.
Valves: 4 Renssalaer 42-inch gates valves weighing 23,000 pounds each.
Weight of penstock and receiver: 225 tons.
Weight of water therein: 340 tons.

WATER WHEELS.

Type: ellipsoidal, tangential.
Builders: Abner Doble Company, San Francisco.
Governor: Lombard, actuating, needle-regulating nozzles.

	Main Sets.	Exciter Sets.
Number of wheels per set.	6	1
Number of sets.....	4	2
HP. capacity per set.....	2500	150
No. of nozzles per wheel..	2	1
Revolutions per minute..	300	300
Lbs. weight per set.....	100,000	...
Diam. of wheels—inches..	45	45
" " shaft " ..	9	...
" " jet " ..	3⅞	3
Material of buckets.....	Steel	Brn'ze
Length of wheel shaft....	24′ 5″	....

ELECTRICAL EQUIPMENT.

Generating Station. Generators: main sets, four 1500-kw., two-phase, 7200 r. p. m., 1000-volt, Westinghouse revolving-armature, running at 300 r. p. m. Exciters: two 75-kw. 125-volt, Westinghouse multipolar running at 300 r. p. m.
Transformers: twelve 1000 to 15,000 or 30,000 volt, oil-insulated, air-cooled Westinghouse, weighing 10,850 pounds each, I. S. C. oil, manufactured by the New York Lubricating Oil Co., being used. Deliver three-phase current to line by the Scott system.
Lightning arresters: Wurts.
Contractor: Westinghouse Electric and Manufacturing Co.

POLE LINE.

Character of lines: 3-phase, 3-wire.
Length of Seattle line: 31 miles; total weight: 67,000 pounds.
Diameter of Seattle line: 26 inches.
Length of Tacoma line: 44 miles; total weight: 72,000 pounds.
Diameter of Tacoma line: 23 inches.
Line: two 3-phase, 3-wire circuits to Seattle and Tacoma respectively.
Line wire: aluminum, furnished by the Pittsburg Reduction Co.
Distance between poles: Seattle line from 90 to 150 feet; average, 110 feet. Tacoma line: average, 150 feet. Average winter sag: 15 inches.
Poles: cedar, 9x13 inches x 36 feet (standard) to 154 feet (maximum).
Ties: No. 8 B. & S. gage, aluminum.
Joints: aluminum tube or sleeve joint,* length, 9 inches; thickness of walls, $\frac{1}{16}$ inch.
Capacity at 25,000 volts and 80 per cent. power factor: Seattle, 4000 kw., and Tacoma, 2000 kw.
Insulators: Redlands type Imperial porcelain. Height, 4½ inches; diameter, 6½ inches; weight, 4 pounds each. Furnished by C. S. Knowles, 7 Arch street, Boston.
Pins: locust, paraffined.
Cross-arms: 4½x6 inches by 8 and 10 feet Oregon pine.
Transpositions. Power line: six transpositions on either side of Renton, each being between poles 6 feet apart and consisting of one-third turn in circuit. Telephone line: transposed each fifth pole.
Resistance of each Seattle line: ohmic, from 84.5 to 88 ohms, according to temperature; induction at 7200 r. p. m., 54 ohms. Tacoma line: ohmic, 76 ohms.
Sub-stations: at Issaquah (50 kw.), Renton (50 kw.), Auburn (50 kw.), Seattle and Tacoma.

*Described in THE JOURNAL for July, 1899; Vol. VIII, page 27, *et seq.*

the age of twelve, when he was apprenticed to a country store where he served until youthful ambition took him to other quarters of the country. The Pike's Peak gold excitement began about that time and he started west in pursuit of his fortune, directing his course thither at a time when it was being stampeded to from all sections of the country. He, however, became stranded when he reached Chicago and was unable to proceed further. There he secured temporary employment at ordinary work, but soon obtained an obscure clerkship in a commission house where he earned recognition very rapidly and in the course of a year was serving in a very responsible capacity with Hinckly, Handy & Co., grain merchants. In the course of a couple of years, while Mr. Baker was still a young man, this firm merged into Hinkly, Baker & Co., and later, upon Mr. Hinkly retiring, it became Knight, Baker & Co., and still later William T. Baker & Co., and so continued until Mr. Baker retired to private life in 1883. This firm inaugurated the direct shipment of grain from Chicago to Liverpool without reloading, and during its existence it was the leading house in the West dealing in grain and produce. The largest single cargoes of any lake shipments proceeded from this house. Mr. Baker has served five terms as president of the Chicago Board of Trade. He was president of the World's Fair in Chicago and as its chief executive was a very potent factor in promoting the financial success of the exposition. He has also been president of the Commercial Club of Chicago—probably the most influential commercial body in the United States. He is a director of the American Biscuit Company, Union National Bank and other large institutions. He succeeded Lyman J. Gage as president of the Civic Federation of Chicago, which is a powerful factor in the promotion of good government and law and order in the city of Chicago. Of late Mr. Baker has been devoting his time to his private investments and particularly to the development of the Snoqualmie Falls Power Company, of which he is the founder and sole owner. Politically, Mr. Baker is a Democrat of the Cleveland school.

Chas. H. Baker was born November 30, 1864, in Chicago. His education was in the public schools of Chicago, the Harvard preparatory school and in Cornell University, from which institution he graduated as a civil engineer in 1886. He obtained employment at this time in a surveying party in Dakota under the Chicago and Northwestern Railway Company, but the emoluments in this work were insignificant and later he bettered his condition by proceeding to Seattle where he obtained employment on the Seattle, Lake Shore and Eastern Railroad, which was then a new concern in process of construction. He was soon promoted to the charge of maintenance of way and retained this position for three years until he resigned to open an engineering office. Seattle at this time was in an era of great prosperity, in which Mr. Baker had his share. He then proceeded to contracting, this work being confined principally to railway work, the Third Street and Suburban Railway of Seattle having been one of his contracts. The firm of Baker, Balch & Co.* was organized about this time, Allen C. Balch, an associate of Mr. Baker at Cornell University, being the partner. This firm continued in general construction work until the panic in 1893. Mr. Balch is at present general manager of the San Gabriel Electric Company of Los Angeles.

CHARLES H. BAKER.

The Merchants' National Bank of Seattle was the only bank to succumb to the hard times and Comptroller Eckels placed it in the hands of Mr. Baker, as receiver. He continued the management of this trust for two years and a half until he began the promotion and construction of the Snoqualmie Falls Power Company, which, upon its organization, was placed under his management and has so continued to the present time.

Vide THE JOURNAL, Vol. VI, pages 102 and 103.—THE EDITOR.

Personal

WALLACE WHEATON BRIGGS, familiarly called "Wally" by his intimates, and "Mr. Wholly Westinghouse Briggs" by those of competitive penchants who do not know him so well, was born in Newark, N. J., on January 6, 1870, although he is a Californian every way except in nativity, which he protests is not to be charged against him. His entry into the electrical field dates back to the days of the California Electric Light Company, when, in 1887, he began to "learn the electrical business" by repairing arc lamps and dynamos in the shop of the company. "There was plenty of repairing to do then," he says, "for in those days large wads of experience came with high frequency." As to these experiences, it is suggested that the reader try to hear them "at first hand," for their interest and humor are best appreciated when they are related in Mr. Briggs' keenly original way of story-telling. When he relates an occurrence the "peak" of his story will be found in his own inimitable mode of narration, its humor factor will be "up in the nineties," and beneath all will be found the deep load line of his wide range of practical experience, together with his fortunate faculty of grasping details and retaining an unfailing recollection of them.

WALLACE WHEATON BRIGGS.

Three years of service in the repair shop of the California Electric Light Company was enough to constitute sufficient warrant for anyone of that period to believe that he was fully entitled to eminence as an electrical engineer, and entitled, furthermore, to receive all the respect, adulation and emolument that pertains thereto. So he started in business for himself, and the first attribute he found, the second he found not, but the third he declares has never existed for him thereto except in youthful fancy. Next he entered the employ of the San Francisco office of the Westinghouse Electric and Manufacturing Company, which at that time was being represented on the Pacific Coast by W. C. Clark, who afterward became assistant general manager of the Westinghouse Electric Company. His latent ability as a salesman was then evidenced, but the then demoralized financial condition of the company enforced rigorous economy, and its San Francisco office was closed in 1892.

Up to about that time the California Electric Light Company had held the electric lighting business of San Francisco as in the palm of its hand, but at last the Electric Improvement Company was organized and entered the field, and as Mr. Briggs so aptly says, "then there were great doings." Again he entered a repair shop, but this time it was that of the Electric Improvement Company, and again he found himself the reaper of much ripe experience—with particular reference to American arc and the old Slattery "induction" types of apparatus. And so it came that when in the spring of '93, the Leesburgh and Lemhi placer mining companies of the Salmon river district, in Idaho, bought an electric plant for lighting their placer mining properties, Mr. Briggs was selected as one fully qualified to install and operate the plant. Accordingly he became electrician of the companies named. His work in this line, together with that done at the North Bloomfield mine, Nevada county, Cal., are believed to constitute the first instances of the use of the electric light in the lighting of hydraulic gold mines. These installations have been described in an article by Mr. Briggs, which appeared in these columns four years ago.*

Mr. Briggs returned to San Francisco in January, 1896, and for a year or more he was engaged in construction work by different electrical and mining companies. In May, 1897, he became sales

*THE JOURNAL, Vol. II, page 6, January, 1896.

agent for the Pacific Coast office of the Fort Wayne Electric Corporation in San Francisco, where, having sold many of the self-starting, self-exciting, self-racking, single-phase Fort Wayne motors then in vogue, he earned lasting distinction in certain southern portions of California by making some of them run. More remarkable yet, a few of them are running still, and this is regarded by his present associates as his crowning triumph. On New Year's Day of 1899, Mr. Briggs joined the selling force of the San Francisco office of the Westinghouse Electric and Manufacturing Company, and though but two years in its service, his sales for the year just closed are eminently satisfactory to himself and his employers. He is in brief one of the most successful salesmen of heavy electrical apparatus to be found west of the Rockies. He is the soul of geniality, and however great his success may rise to be, it will never be beyond that wished him by his countless friends, nor ever approach that of which he is deserving.

HERBERT MCKENZIE ESTES, whose likeness is here given, bears the enviable reputation of being one of the most popular and successful salesmen of electrical supplies to be found on the Pacific Coast. Born on Christmas Day, 1875, in Kansas City, Mo., he is still a young man, but his experience and capacity are such that he already gives evidence of business qualifications rarely possessed by many who are his seniors by a decade or more. He was yet an infant when his parents moved to California, and, being left an orphan when but nine years old, he was adopted into the family of Mr. and Mrs. F. A. Estes, who live on a fruit farm near Oleander in Fresno county. It was through their benevolent tutelage that the lad was reared into manhood. Country life, however agreeable it might be, was not to the liking of "Bert" Estes, as he was then, and is now, popularly known; so at the time of the Midwinter Fair he came to San Francisco where he shortly afterward found employment as a general utility man in the since-absorbed electrical supply house of J. W. Brooks & Co., with which, and its succeeding concern, the Brooks-Follis Electric Corporation, he remained until December, 1899, when he resigned in order that he might accept a position as salesman with the electrical department of the Dunham, Carrigan & Hayden Company, San Francisco. Mr. Estes' rise with the latter concern was very rapid, for within a few months after having entered its employ he was promoted to the managership of its electrical department, and so successfully did he administer the trust imposed upon him that he placed the electrical department of the business upon a most satisfactory plane.

HERBERT M'KENZIE ESTES.

In the meantime, Charles F. Sloane had established himself as Pacific Coast sales agent for several of the largest and most important American manufacturers of electrical apparatus and supplies. Under his able management a business of great value has been developed. Among these agencies are those of the Standard Underground Cable Company, Pass & Seymour, the Crouse-Hinds Electric Company, the Hemingray Glass Company, the Waclark Wire Company, and the Electrical Engineering Company's incandescent electric lamp works. To such magnitude had Mr. Sloane's business grown that it became necessary about the first of the present year to further increase his selling force, and accordingly an offer was made to Mr. Estes which resulted in his resignation from the Dunham, Carrigan & Hayden Company and his entering into the employ of Mr. Sloane. The electrical trade of the great West has already made the acquaintance of Mr. Estes in former capacities, and it is perfectly safe to say that it will be glad to see and hear far more of him in his present one.

EDWARD S. COBB, the well known mechanical and hydraulic engineer, and of the late engineering firm of Cobb & Hesselmeyer, has moved from San Francisco to Los Angeles, where he is located in the Homer Laughlin Building, 315 South Broadway. Incidentally, an evidence of Mr. Cobb's unusual engineering ability is found on another page in this issue descriptive of the great Cobb truss wheel at Mullan, Idaho.

F. M. RAY, who is well and most favorably known to the electrical interests west of the Rockies through his ten years' association with the old Thomson-Houston and the General Electric companies as manager of their supplies department in San Francisco, has accepted the position of assistant to E. J. de Sabla, president and general manager of the Bay Counties Power Company.

G. IRVING KINNEY has resigned the assistant managership of the electrical department of the San Francisco Gas and Electric Company, and beginning February 15th, will become identified with Jno. Martin & Co. as selling agent.

Miscellany

COSTS OF HYDRAULIC WORK.

ACCORDING to L. K. Sherman, in a paper recently read before the Western Society of Engineers,* specific instances of exact costs of hydraulic lines do not mean much, as numerous local conditions must be taken into account. Nevertheless it is of interest to note that the paper referred to gives the following as costs of Western waterways:

Cost of tunnel in San Bernardino Mountains, 5x7 feet, $8.00 per foot.

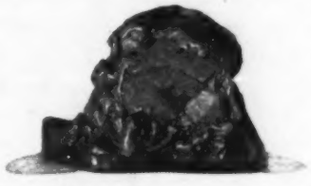
Cost of tunnel in San Gabriel Mountains, 5x6 feet, $3.50 per cubic yard.

Cost of 48-inch wood-stave pipe line near Redlands, Cal., $2.08 per foot.

Cost of 72-inch wood-stave pipe line near Ogden, Utah, $6.00 per foot.

AND THERE ARE OTHERS.

DONALD B. OLSON, Manager of the Dawson Electric Light Company, of Dawson City, N. W. T., has earned the distinction for himself of being the "banner" subscriber to THE JOURNAL, and for THE JOURNAL, of placing it in the much-sought-for position of possessing evidence of the highest esteem and confidence that a subscriber can bestow. This token is in the form of a subscription to THE JOURNAL, accompanied by a nugget from Bonanza Creek district, with instructions to send THE JOURNAL "as long as the nugget holds out and longer." This message and the nugget were borne to THE JOURNAL by Rufus B. Keeler upon his recent return from the Klondyke country, and Mr. Keeler is now employed in the Sacramento-street sub-station of the Independent Electric Light and Power Company of San Francisco. As for the nugget, a photograph of which in exact size is here reproduced—it contains twelve dollars in gold, hence pays Mr. Olson's subscription for *twelve years in advance*.



Albert Sechrist, the leading electrical supply and fixture merchant of Denver, Colo., is another subscriber who does not propose that his files of THE JOURNAL shall be broken because of the accidental non-payment of his subscription, for he is fully paid up in cash to and including the issue of December, 1910.

HOW BELTS SHOULD BE RUN.

Belts should always be run grain or hair side to the pulley. L. P. Degen, the well known Western authority on and manufacturer of belting, states that a belt made of firm leather, cut from the back or center of the hide, run grain side to the pulley, will draw 34 per cent. more than flesh side to the pulley; 48 per cent more than rubber; 121 per cent. more than canvas.

*Reprinted in *The Engineering Times* (London), Vol. V, page 29, 1901.

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Conducted by GEO. P. LOW.

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EDITORIAL.

THE HAZARD OF THE 'PHONE.

There is hardly an operator of high potential transmission apparatus who uses the telephone without some trepidation. However loyal he may be to his employer's interests, and however faithful he may be to the precept that extols the virtues of minimum investment in plant, he always feels that the present practice of running telephone line circuits on the same poles with high-tension transmission lines is hazardous. No one has yet had the financial hardihood to run telephone wires on independent poles in any instance wherein circumstances were such that a pole line carrying transmission circuits was to be found near by. Nor, in fact, has such a course been really necessary. Indeed, it has for several years been the policy of the Bell telephone interests to acquire exclusive rights to carry telephone wires on each and every transmission pole line that has been built in the West. No matter as to the route of these pole lines, no matter whence they come or whither they go, there rights have been acquired and today it is almost if not quite impossible to find a high-tension long-distance transmission system in California at least that does not carry one or more telephone circuits owned and operated by the Bell telephone interests. Of course these rights have not been assigned by the transmission companies without pecuniary advantage to themselves; and, on the other hand, it goes without saying that each pole line right thus acquired by the Bell interests is one less pole line right that may be acquired by any independent telephone enterprise.

The wisdom of such arrangements, when viewed from a business standpoint, is unimpeachable; but surely, the present methods of carrying them out are weak and hazardous to life. Furthermore, however great such hazards may be, they are altogether unnecessary. Troubles on transmission lines occur with lessening frequency, but nevertheless, line troubles, and boys with baling wires, and felonious marksmanships, do occur; and each such occurrence, aside from other damage, may throw a deadly potential into each and every telephone booth on the system. Fatalities of this nature are not without precedent, but their recurrence can and should be made impossible.

To cite a single fatality: A hunter shot an insulator from the pole line of one of the transmission companies in northern California. The destruction of the insulator caused the main line, which carried energy at a potential of 25,000 volts, to fall upon the telephone wire beneath. A few seconds later an employee, noting some disturbance on the system, went to the telephone and was killed in attempting to use the instrument. More than this, the miscreant who shattered the insulator on the line was responsible for the death of that employee and, as such, is guilty of manslaughter if not of murder. The crime can not be cloaked; it admits of no palliation. So much for the evil, now for its removal.

Telephone engineers have long been familiar with the use of the very simple appliance called the repeating coil, or, as they say in Europe, the translator. It is simply a transformer with any desired ratio of windings and is cut in in instances wherein a grounded line is to be connected to a metallic circuit, and otherwise. Repeating coils possess a minor disadvantage in that it is often troublesome to ring through them when long lines are used, but this difficulty may be obviated by ringing direct to line without the intervention of the usual hand-turning magneto paraphernalia. Under these conditions there appears to be no reason why the repeating coil should not be made of sufficient insulation resistance to afford immunity from "sneak" current of fatal pressures. If these potentials chance to equal the line pressures, of course the repeating coil could not be expected to withstand them, hence other means—such as, for instance, electrostatic potential indicators—must be provided to give indication of a dangerous potential upon the telephone system.

But to revert to the independent ringing of telephone signals: there are several ways of accomplishing this result, and local conditions must determine the best for each case. The potential of a hand-driven magneto in ordinary service ranges between 60 and 75 volts and its periodicity is in the neighborhood of 3000 alternations per minute. This voltage is exceeded by as much as twenty per cent. in long lines, and the periodicity that is permissible is by no means inflexible—in fact one transmission in California has experienced considerable success in ringing magneto bells with current alternating at sixty cycles from 110-volt secondary wiring through a series of two sixteen-candlepower incandescent lamps. The suggestion for a better method than this was, however, given in these columns some four years ago* in an article descriptive of an arrangement devised by Mr. F. E. Smith

*THE JOURNAL, Vol. I, page 90, October, 1895.

of San Francisco for dispensing with the use of magnetos. It is still in constant use and its absolute reliability has thus been amply demonstrated during the six years or more that have intervened since it was installed.

To apply the Smith ringer to the telephone system of a transmission line necessitates placing two collector rings on the armature shaft of a small direct-current motor—the old Edison bipolar fan motor with armature windings resembling the coils of the armature of the Brush arc dynamo is a good type—and connecting these slip-rings at diametrical points of the armature circuit so that the machine, when supplied with direct current, may be operated as a direct-current alternating-current single-phase rotary. The usual exciter voltages, when applied to the direct-current side of the rotary converter, will give a potential on the alternating-current side that will be suitable for ringing magneto bells on long lines; but if the exciter voltage is too low for this purpose the alternating-current potential may be raised as necessary through a small step-up transformer having a maximum capacity of about 150 watts. Of course, the speed of the motor should be brought down to, say, 1500 revolutions per minute in order to give the best ringing frequency to the line. In sub-stations or other places where direct current is not available, the only alternative is to use a small motor-generator set that will, through a driven magneto or otherwise, deliver a suitable ringing current. The energy expenditure does not exceed 100 watts per station, hence is inconsiderable.

With such a simple and inexpensive piece of apparatus, the hand ringing of bells, with its direct connection to line, is dispensed with, for the ringing circuit from the rotary, for instance, may be thrown upon the line by simple double-pole contacts which may be made to be rapid in operation and proof against conveying shocks to the party operating them. Then, having finished bell signaling, and if the electrostatic indicators show the line to be clear, the conversation may be proceeded with through the repeating coils and hence under minimized risk.

The execution of these and kindred suggestions will entail some experimenting as well as the annoyances attendant to a changing over of systems, but the saving of a single life thereby will repay a thousand fold all that it will have cost.

THE NEW CENTURY EDITIONS.

The first of the century has ushered in some really remarkable editions of well known engineering publications, among which, in the electrical field, stand first the "Twentieth-Century Number" of the *Electrical World and Engineer*, and the "Historical Number" of the *Electrical Review* of New York. Each is superb in its own inimitable way, for while the former is of the greater technical value, it is positively refreshing to read the fiction-like reminiscences of pioneer days of the electric science.

Then, in more general lines, comes *The Engineering Magazine* in a mastodonic magazine form known specifically as the "Works Management Number," with 340 pages of body matter and nearly 300 pages of advertisements. It is, in brief, a handbook for works managers and describes with conclusive detail the business methods of the world's greatest industrial leaders, all to the end that the works manager may find a guide to practical solutions of modern industrial management. The edition is invaluable and, in its own line, is without a peer.

Finally, an agreeable surprise was given in the appearance of *Mining and Metallurgy* on New Year's Day. This publication was formerly *The Mining and Metallurgical Journal*, of Los Angeles, but its base has been changed to New York where it is now published by W. J. Johnston whose ambition and untiring energy gave *The Electrical World* to the electrical world. It is safe to say that those who predict the rapid rise of *Mining and Metallurgy* to fame and fortune will not be proven by time to have erred in their prophesies.

Telephony is the title of a new monthly telephone publication which about counterparts THE JOURNAL in point of size and color of cover. It hails from Chicago, the home of *The Telephone Magazine*. Each is anti-Bell in tendency—the latter avowedly, the former inferentially—and while every telephonist will welcome *Telephony* to the shelves of his library, he will do so with the feeling that the older publication has not been found wanting. Artistically and typographically *Telephony* is good, and if it holds such well-versed contributors as many of those whose names appear in its initial issue, its success would seem to be assured. And if, perchance, its publishers should come to a realization that success is to be found in the direction of technical rather than in the however-amusing short-story literature of the telephone and will devote their energies to accomplishing that end, then all doubt concerning the outcome of the venture will be swept away.

Apropos of twentieth-century editions, it may be noted in passing that although this issue of THE JOURNAL is its first of the new era—and incidentally of Vol. XI—it has not taken occasion to extend lamentations over the death of the old century nor jubilations over the birth of the new one. The wake and the christening have been indulged in sufficiently by other periodicals, but there is nothing special about this issue, as JOURNAL editions go, for it is but a regular number that describes a long-distance electric power transmission in a style that has long since been familiar to its hosts of readers. That the subject of the Snoqualmie article is handled in an able manner and with fullness and accuracy goes without saying, as will the equal truth that this single issue of THE JOURNAL is well worth the cost of a year's subscription to any engineer, whether he be of mechanical or electrical or civil or hydraulic attainments.

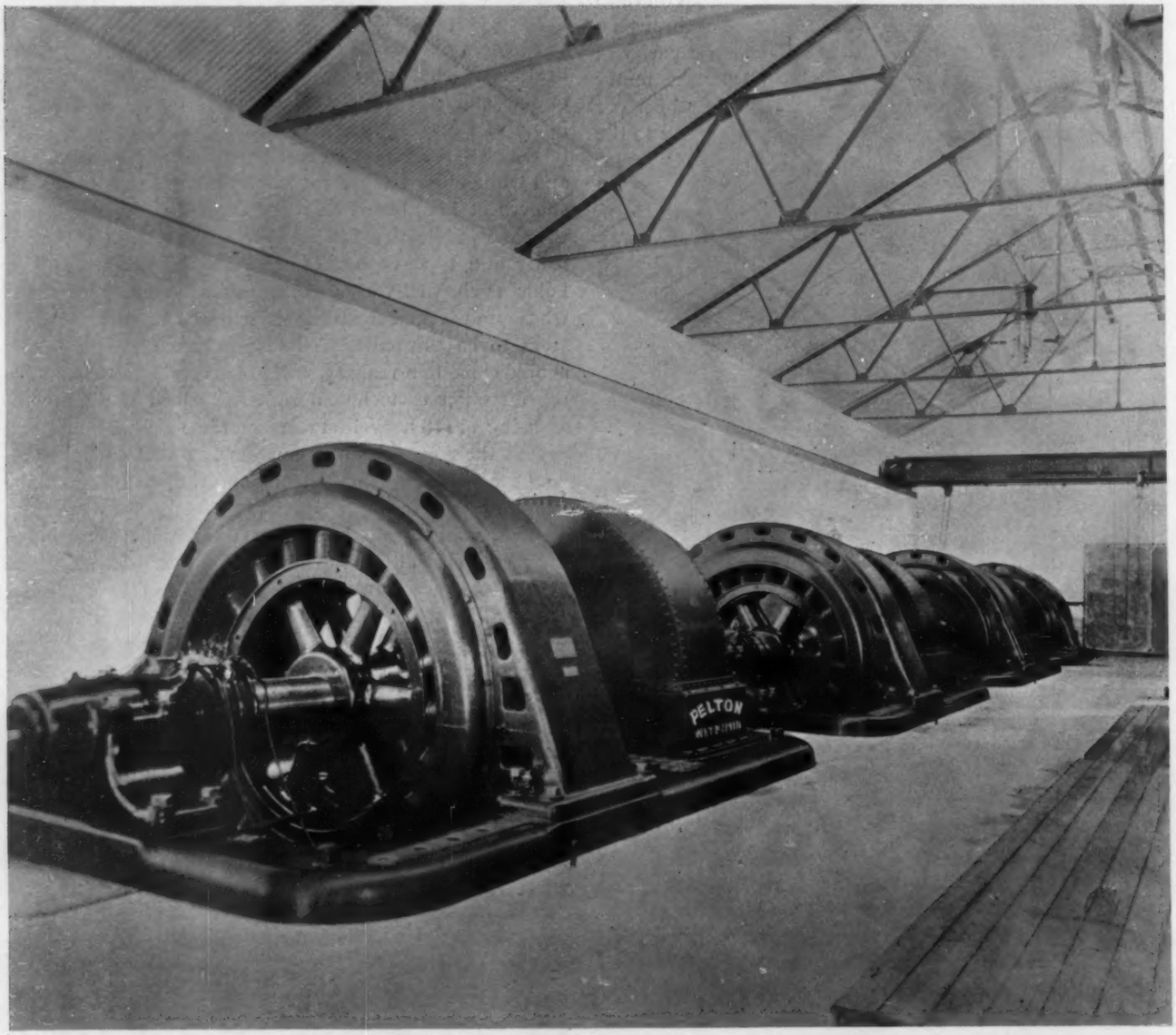
In the next number THE JOURNAL will resume the publication of the series of articles entitled "Industrial Gas," by Frank H. Bates, the well-known gas engineer, who has just returned to San Francisco after an extended tour throughout the East.

Some Recent High-Head Pelton Water Wheel Installations.

BY GEO. J. HENRY, JR.

EXTRAORDINARY progress has been made during the last few years in the development of tangential water wheels and so marked has this been that now their manufacture has been brought to such an eminent degree of perfection as to make the gain of a single per cent. in efficiency a notable achievement. In fact it is impossible to see wherein the present high efficiency of the best type of modern tangential water wheel can be further improved upon, unless it be in the direction that will result from the education of the actual users of the wheels concerning the relations that exist between speed and jet velocity, between jet diameters and power delivered under given heads, and such other matters which, neglected through ignorance, indifference or otherwise, result in inefficient operation. Tangential water wheels are now being built in strict conformity with the principles of exact hydraulic science as suggested by theoretical research and demonstrated by actual practice to be absolutely correct. And the result is that but very little, if any, further improvement in their efficiency beyond the present performance of the latest types need seriously be expected.

The history of building tangential water wheels has followed the identical lines of the experience of other manufacturing industries wherein a pioneer concern has proven sufficiently progressive to keep itself not only abreast with, but actually ahead of, the spirit of the times. Such pioneer concerns employ only the best engineering talent along the lines of their own specialties that can be found; they instantly adopt each and every idea that their own or the experience of others may suggest as tending to improvement, be it however radical; they investigate the worth of everything new pertaining to their business and if it be of sufficient merit in the improvement of the quality or efficiency of their product it is immediately adopted to the mutual advantage of their customers and themselves. Such concerns are generally of long-established standing, they have abundant means, and, above all, the best is none too good for them, whatever be its cost.



INTERIOR VIEW OF THE SANTA ANA STATION OF THE EDISON ELECTRIC COMPANY, OF LOS ANGELES, SHOWING PELTON WATER WHEELS MOUNTED WITH 750-KW. GENERATORS.

A fitting exemplification of these business precepts is found in The Pelton Water Wheel Company, of San Francisco and New York, which was the very first concern to introduce the tangential type of water wheel. So thoroughly did its wheels perform their allotted work even in those early days of the industry, that now tangential water wheels of every make are more generally known the world over as "Pelton type" wheels, than they are by any other name — even than by that of their builders.

From its very outset the Pelton company has restricted its energies solely to the manufacture of Pelton wheels, hence its experience, numbering some twenty years, has been that of a specialist practicing in almost every known application of water power in every country of consequence on the globe. As evidence of the accuracy of the latter statement is appended the accompanying list of localities in which, during the past few years, Pelton water wheels have been installed for electric lighting or power transmission purposes alone, together with the number of such installations and the aggregate horsepower of each. The grand total of these installations is 231 electric power stations, developing 150,708 horsepower by the use of Pelton wheels. This company has now in actual operation more than 9500 wheels, used for almost every purpose to which power is applicable:

UNITED STATES.	Stations.	Horsepower.
Alaska	4	1150
Arizona	4	535
California	64	47237
Colorado	25	17475
Hawaii	5	1005
Idaho	5	2140
Montana	8	3895
Massachusetts	1	600
New Hampshire	1	150
Nevada	3	1300
New York	1	200
New Mexico	1	120
Oregon	3	765
Pennsylvania	1	250
Utah	8	6335
Virginia	1	70
Washington	6	1430
Wyoming	1	100
Total	142	84757

FOREIGN.	Stations.	Horsepower.
Mexico	22	35720
Guatemala	5	1130
San Salvador	4	1650
Costa Rica	7	2350
U. S. of Colombia	5	1960
Bolivia	1	150
Peru	2	800
Chile	1	650
Brazil	4	3325
Venezuela	3	1460
Island of Trinidad	1	1050
Japan	10	5041
India	3	1100
Australia	2	340
Java	3	2145
Celebes	1	650
Island of Mauritius	1	100
South Africa	3	2700
British Columbia	8	3090
Nova Scotia	2	380
Samoa	1	160
Total	89	65951

PLANT OF THE EDISON ELECTRIC COMPANY, LOS ANGELES.

Illustrated descriptions of some of the most prominent and recent installations of Pelton wheels in electric power transmission service will be of interest. Among these may be mentioned that of the Edison Electric Company, of Los Angeles, Cal., more familiarly known as the Southern California Power Company's transmission. Although this plant has been briefly referred to heretofore it has not been illustrated, and brief reference to its wheel installation is pertinent.

The company utilizes the waters of the Santa Ana River, diverting them from the stream at the junction of Bear Creek and Santa Ana River, carrying water through 11,650 feet of tunnel and 3100 feet of flume to a point on the face of Kellar Mountain, where a drop line is put in consisting of two pipe lines 30 inches in diameter, giving a static head of 728 feet. This pipe line is but 2210 feet long. The flume work is only used where necessary to connect the portals of the tunnels across ravines which may intervene between them. This waterway is a rectangular flume built in such a manner that it can be entirely rebuilt, or repairs made, without taking out the water. The tunnel measures, inside of concrete lining, 7 feet high by 5½ feet wide, and is calculated to carry 6000 miners inches of water if called upon to do so. The drop line is composed of 1350 feet of riveted steel pipe and 860 feet of lap welded flange pipe in each line, having a factor of safety of five to one, different gages of metal in the riveted pipe being distributed to obtain that result. These two pipe lines are intended to carry 4500 miners inches with a loss of 28 feet head, giving a net head at maximum load of 700 feet. These two pipe lines lead into one receiver, which is divided by a gate valve so that each pipe feeds one-half of the receiver, making the hydraulic part of the plant from the forebay to the water wheels two distinct installations, if necessary to run them that way, making it practically impossible to shut down the whole plant on account of trouble with pipe line or receiver.

There will eventually be installed in the power house six 750-kilowatt, three-phase, revolving-field, General Electric type generators, delivering current at 750 volts with a frequency of 50 cycles. These generators, which were especially designed for this plant, have a very low center of gravity. The generator frame is made to conform to the wheel diameter so that the jet striking the wheel is brought below the floor underneath the frame of the generator. In this way the nozzle stands very nearly in a horizontal position, and when diverted from the wheels will throw the stream clear of the power house without striking any concrete or other work which may be disintegrated — a trouble which all high head plants have had to deal with. This jet strikes in a body of solid water about 75 feet from the end of the nozzle; the four Pelton wheels thus far installed are each 84 inches in diameter; the disk for each consists of a solid steel casting with a single web turned all over, having a fit upon the generator shaft 24 inches long, 12 inches in diameter. Each wheel complete weighs 12,000 pounds, is equipped with cast steel buckets and delivers 1200 horsepower at 300 revolutions per minute. The nozzle connections from the receiver to the wheel are also soft steel castings, and one deflecting nozzle jet is used, thus imposing the heaviest strains on any tangential water wheel bucket so far used in actual practice. The plant was installed in December, 1898, and as yet not a single occasion has arisen for the renewal or replacing of a single bucket.

The four units are arranged in the power house lengthwise along one side with the receiver just outside the power house, while the pipe lines enter the middle of each half of the receiver at right angles. One nozzle leaves the receiver opposite each line; the other two on each side of each pipe line. The tailrace from each machine is a tunnel giving free passage for the deflected jet across and underneath the power house floor without striking inside of the tunnel at any point.

The power house, which is 130 feet long by 40 feet wide outside, is equipped with a 15-ton traveling crane. The building is entirely of concrete with an iron roof, having a ventilator the whole length of the top. There are three 30-kilowatt exciters, each direct-driven by a separate Pelton wheel, any two of which exciters are of sufficient capacity to operate all the generators and 150 sixteen-candlepower lamps beside.

THE REDLANDS ELECTRIC LIGHT AND POWER COMPANY.

The most important station of the Redlands Electric Light and Power Company is that known as Mill Creek No. 2 Station, which contains thus far two 61-inch Pelton wheels, each of which drives by direct connection a 250-kilowatt, revolving-field, General Electric generator delivering 11,500 volts direct to line. These wheels are operated under a head of 605 feet and run at 450 revolutions per minute. Deflecting nozzles are used and a single jet is applied to each wheel. These wheels are controlled through geared gate valves operated by shafts which extend through the walls. The two exciters for the generators are driven by 22-inch Pelton wheels that are overhung on the shafts of the exciters. They run at 1050 revolutions per minute and deliver 30 kilowatts each.

THE UTICA HOIST.

The electric power transmission of the Utica Gold Mining Company has also been described heretofore, but in addition to the Pelton wheels used at the generating station therein, the hoist at the Utica mine is driven during the wet months of the year by two Pelton wheels each ten feet in diameter and each actuated by three 4-inch streams. The static head under which these hoist wheels are operated is 375 feet, but the effective head is reduced

to about 275 feet because of the long pipe line. The hoist is of the steam variety, having been built by the Union Iron Works, of San Francisco, and it is still driven by steam when water is not available, but when operated by water power each Pelton wheel is controlled from the engineer's stand by means of hydraulic gates, the reverse motion being obtained by having the two wheels reversed and side by side on the pinion shaft. The rope speed of this hoist is 700 feet per minute and the maximum load is 18,550 pounds, which duty is performed by round ropes wound on taper drums. Two skips are run in balance and a round trip made each seven minutes. The hoist is used for both pumping and sinking.

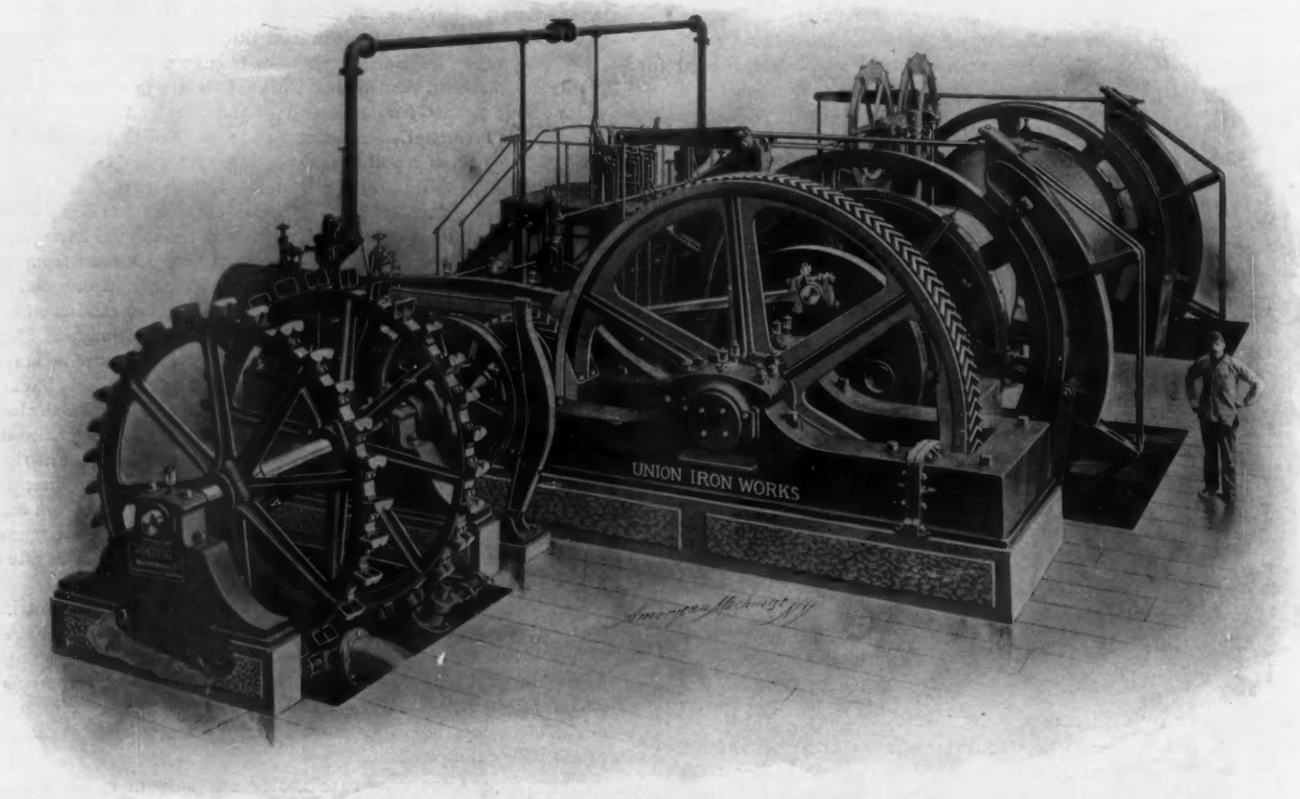
BUTTE COUNTY.

The Butte County Electric Power Company operates a transmission service into Chico, Cal., and to various mining and other industries thereabouts. The water head is 590 feet and the two generators are each driven by a 58-inch Pelton water wheel that is through flexible couplings. The lower housings and bedplate of these sets are of cast iron and the upper housings are of riveted and flanged steel.

A NOVEL HYDRAULIC COMPRESSOR PLANT.

The great flexibility of the Pelton system is well illustrated by the plant recently installed at the Morning mine, Mullan, Idaho. The problem here presented was unique in many ways, requiring that all the available water power be devoloped to best advantage in order to obtain the requisite output.

The plant consists of a 1000-horsepower duplex air compressor with three Pelton wheels mounted directly on the 15-inch shaft connecting the two sides of the compressor. This shaft is about 35 feet long, and is carried in four heavy babbitted pedestal bearings. The water available is limited, and in order to obtain the required power it was necessary to utilize three different streams, affording heads of 1430 feet, 1150 feet, and 140 feet respectively.



HYDRAULIC AND STEAM HOIST AT THE UTICA MINE.

masonry-mounted and direct-connected by flexible coupling to a 400-kilowatt Westinghouse, revolving-armature type, two-phase generator running at 400 revolutions per minute. Cast with these couplings is a 5000-pound steel-banded fly-wheel. A Pelton electric governor is used in connection with the deflecting nozzle of each wheel, and the two exciters are independently driven by 18-inch Pelton wheels that are direct-connected and run 1300 revolutions per minute.

THE GRANITE AND BI-METALLIC PLANT.

The Montana Water, Electric Power and Mining Company operates an electric power transmission for the delivery of electric power to the Granite and Bi-metallic mines nine miles distant. The Westinghouse Electric and Manufacturing Company furnished the electrical equipment and the entire hydraulic plant was installed by the Pelton Water Wheel Company. Two 56-inch Pelton wheels with cast steel centers and cast steel buckets run at 450 revolutions per minute under a head of 680 feet and deliver 900 horsepower each to the Westinghouse polyphase generators

The water from both the 1430 and the 1150 foot head is applied to a single wheel 33 feet in diameter, which diameter is a compromise between the two high heads—taking 80 revolutions of the wheel as the average speed. This 33-foot wheel is the largest tangential water wheel ever made, and in order to withstand the severe strains to which it is subjected it required special construction. The wheel, which is mounted in the center of the compressor shaft, is of structural steel, built up, riveted and bolted, being entirely without cast parts except the hub, which weighs about 12,000 pounds. The spokes are all in tension, and each is susceptible of adjustment in order to true up the rim to which are bolted the buckets; the latter are only 5x7 inches in dimensions, being extremely small in comparison with the wheel diameter. The total weight of the wheel is about 32,000 pounds, and it serves as a fly-wheel for the compressor. The water is supplied to the wheel through two separate nozzles which are mounted one over the other, each being supplied by a separate pipe line.

On either side of the large wheel is situated a 12-foot wheel,

each of which is supplied with a triple nozzle, and receives the water under a head of 140 feet. Each jet of the nozzles is controlled by a cut-off shield and the shields are connected together by suitable levers and links so that they operate in succession, thus maintaining the highest possible degree of efficiency.

Automatic governing is accomplished with these wheels only, the high-pressure nozzles maintaining a constant load on the large wheel. The fluctuations in pressure due to changes in load are extremely small and gradual, and a mercury column was adopted as the most sensitive device for operating the governor. The mercury column is arranged to balance the air pressure of 100 pounds and closes or opens a circuit, which, operating on magnetic clutches, actuates the cut-offs on the triple nozzles, thus varying the capacity of the plant to meet the demands for air at the mine.

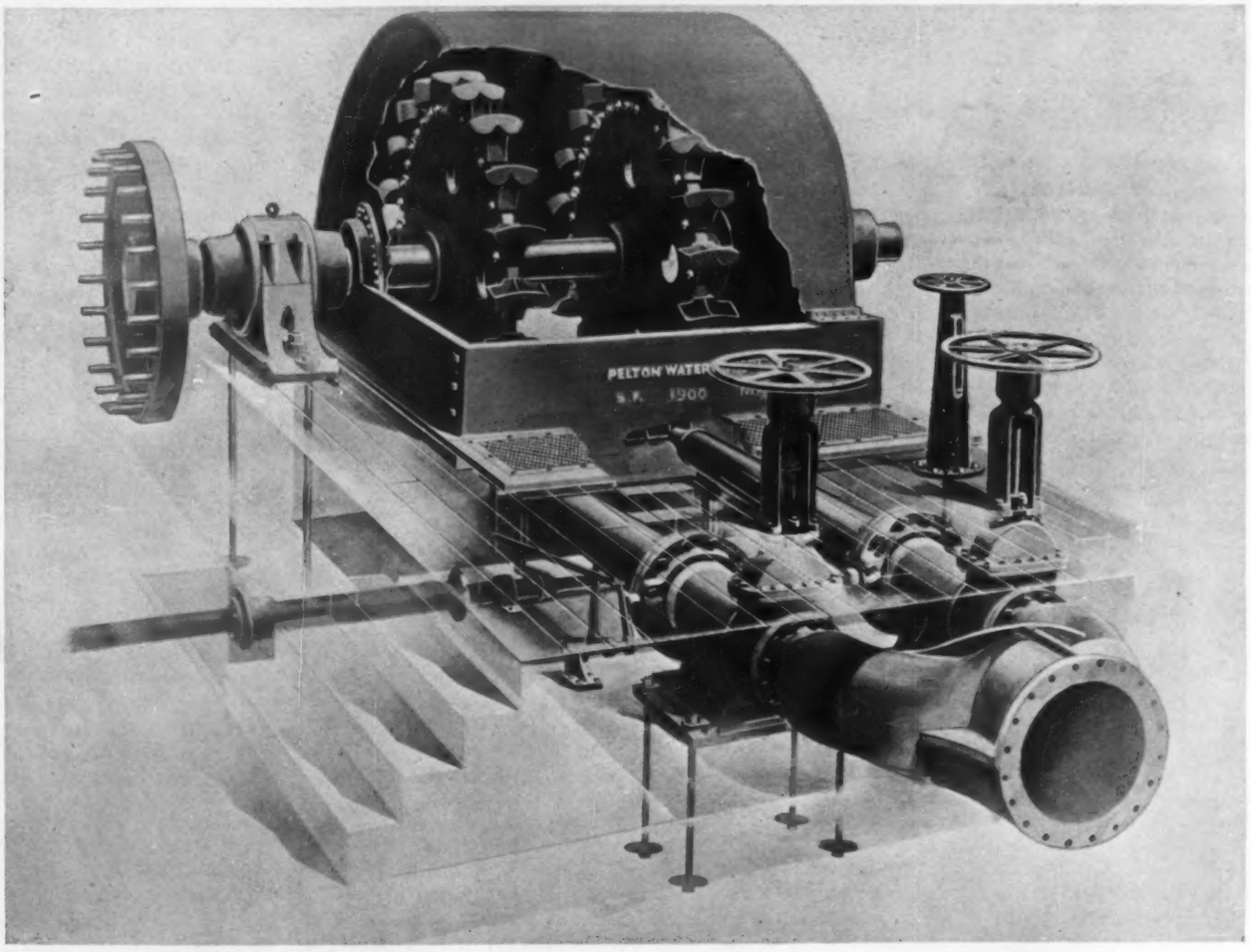
Particular attention is called to the wide variations in the different heads employed and to the manner of adapting them all to one speed, by the simple method of varying the wheel diameter. All belting and gearing losses are thus avoided and the maximum efficiency is maintained. There is also a great difference in the water quantities, the two higher pressures each using a nozzle about 1¼ inches in diameter, whereas the low-pressure stream requires six nozzles about five inches in diameter. The air compressor was designed and manufactured by the Rix Engineering and Supply Company, of San Francisco, and the hydraulic apparatus in all its details by the Pelton Water Wheel Company.

THE NEWCASTLE–AUBURN PLANTS.

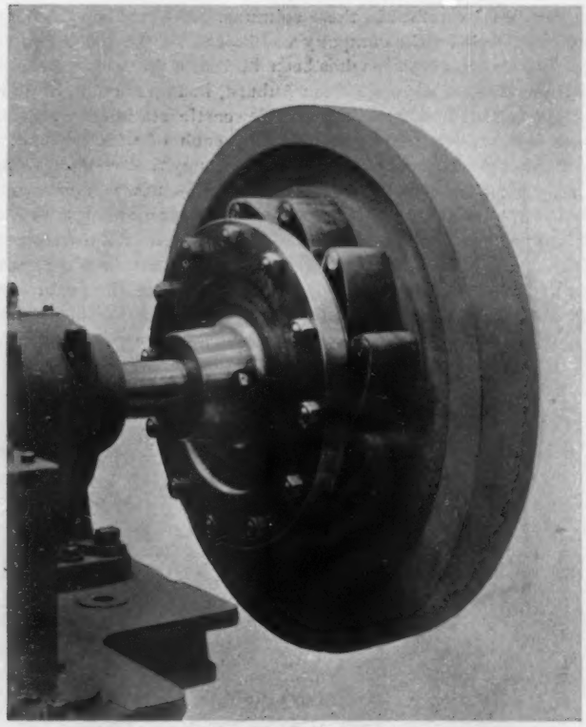
A number of important changes have been made in the generating stations of the Central California Electric Company since its system was described in these columns. At that time the only station operated by the company was that at Newcastle, Cal., but since then a second station has been built at a point on the company's canal some six miles from Auburn, in Placer county. The wheels originally installed in the Newcastle station have been superceded by two new Pelton wheels, each of which has displaced two old wheels and the gain in efficiency that resulted from the change amounts to thirteen per cent. The new wheels are 48 inches in diameter, are of the double-nozzle type and run at 400 revolutions per minute under a head of 430 feet. An interesting feature of the plant is that the lower outlet of the double nozzle has a tip gate to assist in carrying the load during the peak. At present the Auburn power house carries the normal loads and the Newcastle station is thrown in line when the capacity of the Auburn power house has been reached. Water wheel regulation is accomplished by hand-controlled stream deflectors.

THE POMONA PLANT SUPERSEDED.

The historic transmission of the San Antonio Light and Power Company, known the world over as the Pomona plant, has at last, after nearly nine years of service, passed into other hands and is now owned by the Sierra Power Company which has installed a new station on the San Antonio creek below the old Pomona power house. This new station, which has superseded the old one, has been equipped with two 54-inch Pelton wheels that run at 430 revolutions per minute under a head of 640 feet. Each wheel delivers 600 horsepower and is direct connected to a Westinghouse revolving-armature generator through a flexible coupling consisting in part of a 56-inch steel-banded fly-wheel weighing 5000 pounds. The old Pomona plant also contained



A 2000-HP. PELTON UNIT FOR DIRECT CONNECTION TO A 1200-KW. GENERATOR AT TELLURIDE, COLO.



FLEXIBLE INSULATED LEATHER LINK COUPLING WITH FLY-WHEEL ON ONE HALF. USED AT THE BUTTE COUNTY ELECTRIC LIGHT AND POWER COMPANY'S PLANT.

Pelton water wheels, *viz.:* two 34¼-inch wheels delivering 190 horsepower under the head of 402 feet then available. The exciters for the old Pomona plant were driven by 14¼-inch Pelton wheels.

TELLURIDE PLANT AT ILIUM, COLO.

Two 96-inch Pelton wheels as a single unit, have been installed recently at Ilium, Colo., by the Telluride Power Transmission Company. Together they deliver a maximum of 2000 horsepower through a ten-inch shaft at 200 revolutions per minute to a 1200-kilowatt General Electric three-phase revolving-field generator. The wheels operate under a head of 500 feet, and their power is transmitted through a leather link coupling six feet in diameter.

THE PELTON LINK COUPLING.

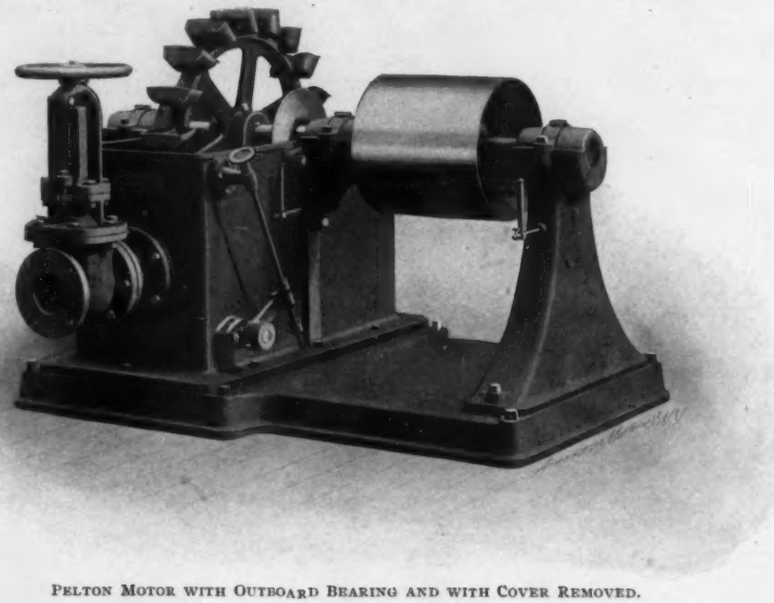
These couplings, as used at Ilium, may be described as representative of the Pelton type of flexible coupling. They are, as stated, transmitting 2000 horsepower, and consist of two disks six feet in diameter. Each carries 24 forged steel pins two inches in diameter, inserted in taper holes on a four-foot circle. The opposing pins of these disks are connected by 24 leather links, six inches wide, made up of triple leather belting wrapped up to a thickness of one-half an inch. The accompanying table gives the result of an expansion test of one of these links. It should be remembered that the link tested was designed for a maximum working strain of 370 pounds per square inch, while the test applied reached 1400 pounds per square inch, or 4.3 times the working strain. It is stated that these links have never been known to fail in service or to require repairs in any way.

A TEST OF THE PELTON TYPE FLEXIBLE LINK COUPLING.

Load in Pounds.	Length of Link in Inches.	Time of Test.
None	$13\frac{5}{16}$	0
4200 pounds	$13\frac{9}{16}$	10 minutes
4200 pounds	$13\frac{5}{8}$	30 minutes
4200 pounds	$13\frac{3}{4}$ scant	1 hour
4200 pounds	$13\frac{3}{4}$ scant	$13\frac{1}{2}$ hours
No load	$13\frac{3}{8}$ scant	26 hours

THE KESWICK TRANSMISSION.

The generating station for the electric transmission of the Keswick Electric Power Company is being installed at Shingletown, some 20 miles from Redding, Shasta county, Cal., whence power will be transmitted for operating the copper properties of the Mountain Copper Company, the Bully Hill mines and other industries of that vicinity. Water for the operation of the plant is being taken from Mill Creek and carried through ditching and fluming several miles in length to the penstock, whence it will be delivered to Pelton wheels at a head of 1170 feet through about 7000 feet of 28-inch pipe. These Pelton wheels are three in number, and are 79 inches in diameter. Each has a single jet delivering a stream which is regulated by a deflecting nozzle. The capacity of these wheels is 1650 horsepower each, and they drive through flexible link couplings three Westinghouse generators of equivalent capacity. The sets are enclosed in cast-iron housings, constructed to minimize noise, and they are equipped with Pelton patented centrifugal disks and pockets to prevent the leakage of water along the shaft without friction. The stream of each set is controlled by a 12-inch Pelton gate valve with outside screw yoke and roller thrust bearings—which is quite a necessary feature in view of the fact that the thrust is about 25 tons. The plant is laid out with two generators, three water-wheel units and four special couplings, so that either wheel may drive either of two generators. Self-oiling bearings, with rings 7½ inches in diameter are provided, as are also ball and socket babbitted journal bearings, made specially rigid to withstand the enormous strains that will be imposed. Each bearing has two heavy turned bronze parting rings which enter unusually large oil wells, and the entire construction is of such thoroughness that it may be accepted as representative of the very best possible practice.



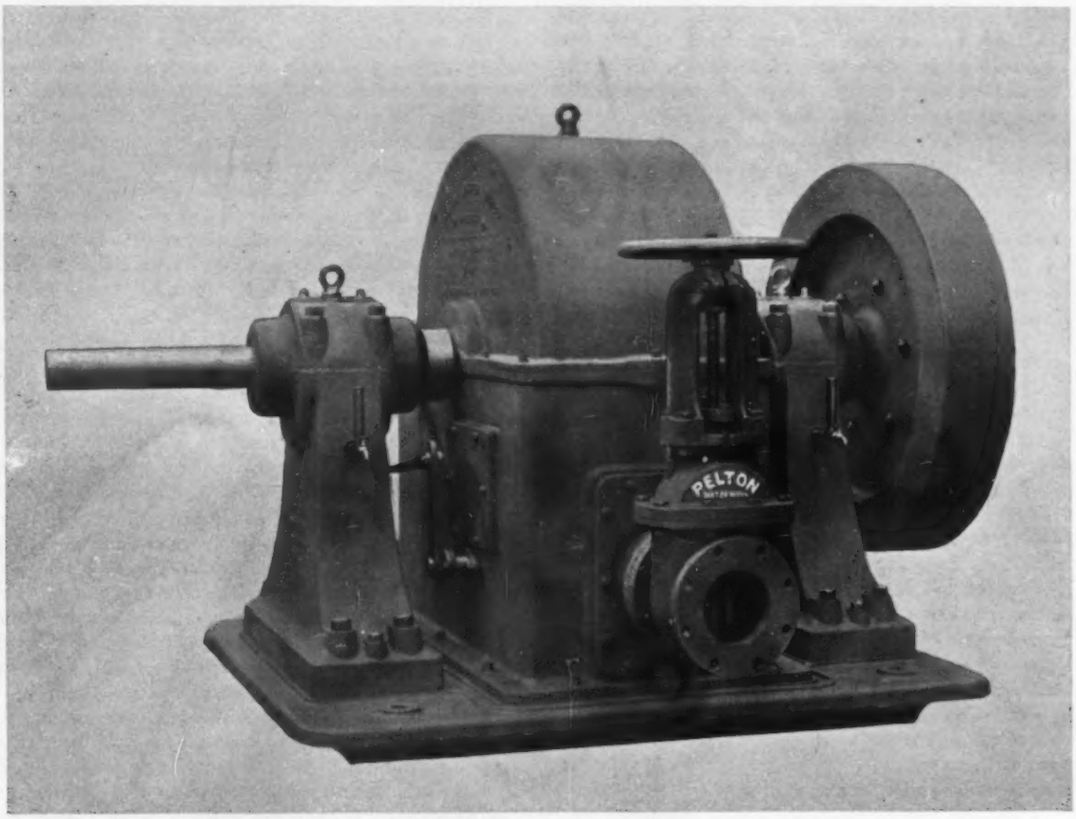
PELTON MOTOR WITH OUTBOARD BEARING AND WITH COVER REMOVED.

THE RECORD OF A PELTON WHEEL.

A fitting conclusion to this description of some modern Pelton water-wheel installations is found in the following clipping from a current issue of the Virginia (Nev.) *Enterprise:*

"The motive power in the Kinkead Mill is furnished by a Pelton

water wheel 18 inches in diameter, running under a pressure of 200 pounds to the square inch, and using 12 miners inches of water in 24 hours, which develops 15 horsepower. The wheel makes 1000 revolutions per minute, which gives a periphery speed of 4500 feet per minute, equal to 1227 miles in 24 hours. As the wheel has been running almost constantly for five years, the buckets have traveled over 2,000,000 miles. The belt on the wheel travels 1000 feet per minute, or 272 miles per day, and has traveled during the five years about 500,000 miles. While the belt has been renewed six times during the five years, the shaft on the wheel has been renewed only once, and the buckets have never been replaced. During the five years the little wheel has furnished power to crush over 60,000 tons of ore. The wheel only cost $125 originally, and the repairs on it for five years did not exceed $10."



IRON-MOUNTED THREE-FOOT PELTON WHEEL WITH FLY-WHEEL HALF OF FLEXIBLE COUPLING IN USE IN THE HAWAIIAN ISLANDS.

A SIMPLE TEST FOR LAGGING CURRENTS.

A VERY simple practical method for determining whether the current in a single-phase alternating current is leading or lagging, is suggested by Professor Silvanus P. Thomson* in cases where it is possible to close and break the circuit, and if the electromotive force is sufficiently high. If there is a spark on closing the circuit and none on breaking it, then the current is leading the electromotive force. Conversely, if there is a spark on breaking the current then the current is either lagging behind the electromotive force or is in phase with it.

"Halsey's Slide Rule" is the simplest and most concise exposition of the principles and modes of using the slide rule so far published. By mail for fifty cents.

"I have read the JOURNAL with much interest."—*Sir W. H. Preece, London.*

American Electrician, Vol. XII, page 84, February, 1900.

Telegraphy

OCEAN CABLE MAKING AND LAYING.

BY JOSEPH W. MARSH.

IN whatever form electrical energy is utilized by man, one adjunct is indispensable, namely, the medium for carrying that energy from the place of production to the place of consumption. If Marconi's and Tesla's systems of wireless transference of electrical energy could be applied to practical conditions, the cable makers would soon, like Othello, find their occupation gone; but while no thinking person will be rash enough to say "thus far and no farther" to these wizards, and they probably will accomplish wonders in the future, yet electrical transmission is so complex and varied that it will be many decades before wires and cables are rendered needless, if indeed that time ever comes.

All material substances will conduct electricity; some of them, as, for instance, silver, copper, aluminum, iron, lead, and water, in the order named, offer relatively little resistance to the passage of the current and are therefore spoken of as conductors. Among these, copper has taken the first rank in the manufacture of insulated wire and cables, because it combines in a higher degree than any of the other metals, the qualities of ductility, strength and conductivity, with generally reasonable price and minimum size.

Other substances, as, for instance, glass, porcelain, mica, gutta-percha, india-rubber, dry air, cotton and jute yarn, paper, resin and hydrocarbons, offer so much resistance to the passage of the electric current that they are termed "insulators," and are all used in one way or another to insulate, or prevent the escape of the electric current from the conductor. Thus electric wires on poles and housetops are practically always attached to glass or porcelain insulators; mica is used extensively in the manufacture of electrical apparatus, while yarn, paper, india-rubber and gutta-

percha, because of their easy manipulation, are applied to wires for use in cables or inside of buildings, or overhead in cities when the current to be transmitted is one that would be dangerous to the public. The resins and hydrocarbons are only used for saturating the fibrous insulators.

A water-tight metallic covering for the insulated wires is essential in all underground cables; this necessity is quite apparent when the insulator is cotton or jute yarn or paper, since it is well known that these substances are not impervious to moisture, and the least path of moisture through the insulating covering would render a cable worthless. Guttapercha and India rubber coverings, when properly applied and maintained are absolutely impervious to moisture, but being vegetable in origin, their value is more or less quickly, but none the less surely, destroyed by the action of gases, acids or street drippings, frequent alternations of wet and dry conditions, and oxidation due to simple exposure to the atmosphere. A lead cover excludes all these enemies of good insulation, and was generally adopted from the very beginning of American cable manufacture. It took the foreign manufacturers and users a long time, however, to find out that America, though starting at a much later period in the commendable work of putting the wires underground, had very quickly distanced them in the methods of manufacture and installation.

AMERICAN TYPES OF CABLES.

No very long submarine cables such as are laid across the Atlantic, have been made in the United States, because sufficient demand or encouragement has not existed up to this time. This does not mean that no iron-clad or armored cables have been produced in the United States, but only that the production has been restricted to comparatively short lengths for crossing rivers and bays, or the smaller lakes or straits, and for the use of the government in its harbor defenses, in short lines of communication in harbors and with lighthouses which have also been used as watch towers, and in Alaska and the Philippines for connecting various military posts with the district headquarters. Where very short cables have been required for commercial purposes, and the bottom was known to be soft mud or sand, the ordinary types of underground cables, with an extra thick covering of lead, and over that some wrappings of yarn and canvass, have been found efficient, but quite often the protection of the cable is carried a step further by covering it with a complete winding of steel or iron wires, or steel tapes, to prevent abrasion of the lead, or of the insulating material.

When rubber is used as the insulator in such cables, it is customary to omit the lead cover (unless the water is contaminated by acids or other materials, harmful to india-rubber) since continual submersion in clean water is the most favorable condition under which rubber or guttapercha insulation can be used. All submarine cables supplied to the United States government by American manufacturers have been of this latter type—that is, rubber insulated and iron armored, over a jute bedding or cushion, and, in most cases, a jute covering over the armor wires, to prevent or retard their corrosion. The aggregate purchases of cable since the beginning of the war with Spain have amounted to considerably over 1000 nautical miles.

TRANS-OCEANIC CABLES.

The very highest grade of copper (and none better is produced in the world than our own copper) must be used, so that the least possible resistance, for a given bulk, may be offered to the passage of the current; since a single wire is more easily broken than an equal weight of copper in finer sizes, the conductor is composed of small copper strands—seven to twelve—carefully twisted together into a rope, to give greater strength, flexibility and compactness. Special machinery is requisite for this operation, but most American cable makers already use precisely such machines in their present processes.

In certain mechanical properties india-rubber is superior to guttapercha; it is infinitely tougher, and thus stands rough treatment better; it is not so susceptible to oxidation by exposure to the atmosphere, and will not soften until about 212 deg. F. is reached, whereas, guttapercha will soften at about 115 per cent.; for the last two reasons india-rubber is to be preferred for the shore ends where these cannot be protected from the sun or hot sands. On the other hand, it is contended that high class india-rubber, owing to its great elasticity, cannot be applied in a permanent manner around a wire in tubular form by means of a die-apparatus, as is done with guttapurcha; that the insulating value of vulcanized india-rubber, when submerged, has been known to become reduced by time, rather than increased, as in the case of guttapercha under the same conditions; that the insulation resistance is less uniform in the lengths made at different times and eventually combined into one long section, thus rendering the locating of faults more difficult and expensive; that the process of joint-making must always be more elaborate and troublesome, and the risk of defect greater than in guttapercha; and that pressure tends to actually decrease its insulation resistance, while that of guttapercha is increased. Whatever may be the relative merits or future developments, I do not believe that any American manufacturer would have the temerity to sell and guarantee, or any government official to buy, a cable with india-rubber insulation for the first American Pacific cable; guttapercha is the only insulating material thus far used in trans-oceanic cables since the first trans-Atlantic cable was laid, and we must assume that that is the material that will be used in our trans-Pacific cable.

Guttapercha, like india rubber, is the coagulated sap of a tree, the principal producer being at present the *Isonandra Gutta*. india-rubber is produced in South America, Africa, and the East Indies, while the area of guttapercha production is relatively small—being confined almost entirely to the East Indies, with Singapore as the principal market place; it arrives at the factory in a variety of shapes, such as balls, loaves, and such grotesque animals, human figures, etc., as the crude fancy of the native may suggest to him; it comes loaded with foreign matter, accidental or intentional, and to get rid of these, it is chipped, softened, torn and washed; then it is steamed, crushed, beaten and twisted, and finally rolled into sheets. The sheeted gutta is fed into a die-covering machine, and compressed firmly and evenly in tabular form, and in several layers, around the conductor, to the desired thickness. An air bubble between the conductor and insulator would be disastrous, for when the cable is submerged in great depths, the pressure would force the air out through the gutta, rupturing it and immediately admitting water, whereupon the cable would be useless until picked up and repaired, possibly at great expense. While all machinery used in the preparation and application of guttapercha is very costly and different in detail from that used by American manufacturers in the preparation and application of rubber, and neither class of machinery would serve as a substitute for the other, yet the principle and purpose are substantially the same; to those Americans who have given the subject careful study, there is no actual (though plenty of pretended) secrecy regarding the machinery and processes, and not a few who are now American citizens, or soon to become such, have been employed abroad in these really important departments of foreign cable industry.

The copper conductor, with its guttapercha covering, is now and henceforth referred to as "the core;" after each length of core has been tested in shallow tanks filled with water and found to be perfect, the sections of core, which are usually made in one to two mile lengths, are jointed together to make a single length equal to the capacity of the receiving tank for finished cable.

Jointing is properly considered one of the most difficult and delicate operations in cable making or laying, for upon the perfection of the joints depends the success of the cable. Hands, tools and material are kept scrupulously clean; a few inches are cut off from the two ends to be spliced, and the guttapercha is removed from a few inches of the conductor, the ends of which are then oppositely beveled, brought together, soldered, and tightly wrapped with fine copper wire for about an inch in order to maintain electrical continuity in case the solder should fail to

hold. The guttapercha is then further pared down, heated on each side of the joint, and worked down with the fingers until the copper is completely covered. Additional guttapercha is then applied, layer upon layer, each in turn heated and kneaded with the utmost care to exclude all dust, moisture or air bubbles, and when the joint is finished it is tagged and recorded and carefully tested for size and insulation. In the longest cable every joint can be traced and located.

The remaining operations of manufacture, namely, the application of the jute and the iron armor wires, are merely to protect the core from mechanical injury and to afford the necessary strength for safely placing it on its deep ocean bed, and taking it up again when necessary.

Generally speaking, every ocean cable consists of three types; namely, the deep-sea type, which is made as small and light as possible consistent with the requisite strength for lowering to and raising from the great depths encountered; the intermediate type, which is used in shallower waters, where greater danger of mechanical injury exists and is therefore more heavily armored; the shore-end sections, which are naturally most liable to mechanical injury, fouling by anchors, etc., and are, therefore, the most heavily armored. In other words, as the dangers of abrasion and mechanical injury increase, the sheathing is made heavier to meet the conditions imposed upon the cable. In some localities there is reason to fear the ravages of the *teredo*, but this animal, where it exists at all, is only found in shallow waters, and in these localities the core of the cable is covered with a thin brass tape, which has been found an efficient bar to his progress. India-rubber seems to be immune from the attacks of this pest.

The armoring machines are models of perfection in adaptability of means to ends, are very expensive, occupy a large amount of space, and those for sheathing the intermediate sections and the shore-end sections are enormous in size and weight.

As the finished cable comes from these machines, it is passed along to the tank house, coiled evenly round in uniform layers or flakes into the tank in which it is to lie submerged until the telegraph ship is ready to take it into its tanks. Each flake of the cable is whitewashed to prevent sticking, and the ends are left accessible so that tests can be made at frequent intervals between the time of manufacture and the date of shipment.

While abroad, I had the pleasure of visiting several of these large cable plants and cable ships, one of which latter was loading with submarine cable. Enough cable had been completed and stored in the tank house, and the cable ship was moored in the Thames several hundred yards off shore. A steel cable with pulleys attached was suspended from ship to shore and thence to the tank house, and over these pulleys the submarine cable was rapidly drawn to the vessel by a steam winch and dropped into one of the three large tanks that are permanently built into the ship. The coiling-down of the cable in the ship-tank is precisely like that in the tank house at the time of manufacture, except that the cable is coming in very much faster, and without an instant's stop (barring accident) until the entire length has been stowed away.

LAYING OCEAN CABLES.

There are over forty steamers afloat whose sole business is the laying and maintenance of the world's vast system of telegraph cables; seven of these belong to government administrations, and the remainder to manufacturing and cable-operating companies. Ten of the cable-laying ships are owned by the three largest English cable manufacturers; one of the largest of these cable ships is of about 5000 tons displacement, with a carrying capacity of 8000 tons, and has carried 2500 nautical miles of deep-sea cable in one load. They require a crew averaging about 200 men, including the electrical staff. The cable-gear on such a ship is simple enough but extremely powerful, and, together with the guides and sheaves for the cable, pretty effectually occupies all the space of the main deck that is not taken up by the tanks. The cable, in paying out, passes from its tank, through guides and pulleys, under and over grooved iron controlling-wheels, to and around the paying-out drum, whose speed is controlled by a powerful brake, and then through the dynamometer which indicates the strain that is on the cable, and on to the stern of the vessel from where it is dropped into the sea, quite clear of the propellers.

The picking-up gear is much like the paying-out gear, but more massive on account of the severer duty it has to perform. It is located forward, since the cable will come in over the bow. The ship moves back and forth at right angles to the course of the cable, dragging a grapnel along the bottom of the sea until it hooks the cable, which fact is instantly shown by the dynamometer; the ship is stopped, the picking-up gear is started and if everything goes well the loose end is soon brought on board, spliced to the next section, and the work of paying out proceeds as before. It is usual to lay the two shore ends and intermediate cables first, and then to fill in the deep-sea portion. It is, therefore, apparent that the final splice completing the cable is not subject to test on board ship, and must be dropped overboard with nothing but the anxious hope that it is perfect; but this class of splicing has been brought to so high a state of perfection that the remaking of a splice is one of the rarest occurrences.

TRANS-PACIFIC CABLE.

American manufacturers can provide the ships if need be, can procure the necessay equipment and the skilled men to conduct the work of cable laying. It will be quite apparent too, that while Pittsburg capital and Pittsburg enterprise may and probably will undertake the establishment of the deep-sea cable industry in the United States, the larger and finer part of its manufacture — the assembling of its various constituents — must be done at the seaboard, and in a locality where the telegraph ship can come alongside the works to receive its cargo of finished cable.

From 7500 to 8000 nautical miles of cable will be required to connect our Pacific coast with the Philippines via Hawaii, Midway and Guam, and its cost installed will be approximately $1500 per nautical mile; about 2000 miles additional will be needed to connect China and Japan with the main cable, and a duplicate cable, if undertaken, will of course require as much more. My personal opinion is that the cable should not be duplicated over the same route, but that a second trans-Pacific cable for the United States should go via Alaska to Japan with a spur to Russia.

AMERICAN MANUFACTURE PRACTICABLE.

There is no step in the process of manufacture or installation of such cables that is unknown or unfamiliar to those American cable manufacturers who (as I am aware two or or three have done) have given the subject careful special study and consideration, in addition to their long practical success in the manufacture of underground and submarine cables of the types more common in this country.

The question of ability to produce the Pacific cable in the United States is, therefore, a question of quantity; that is, the building and equipping of the submarine cable factory with plenty of machinery and providing plenty of capital to handle a business of this magnitude; and it is well known that considerations of quantity or size do not at all stagger American enterprise.

The cable should be of American manufacture for the following reasons:

1. Because it can be.

2. To add to our important manufactures one not heretofore extensively carried on.

3. For the benefit of American labor, not merely in the cable factories, but in every tributary branch of production, embracing more or less directly copper and iron mining, cotton growing, cotton and jute mills, and copper and iron wire mills.

4. And last, but not least, for the greater advantage and safety of the nation, by making it completely independent of any foreign country in establishing or quickly restoring telegraphic communication with our outlying possessions and along our coast in case of war with a foreign power.

If the armor plate, the tin plate and the ship building industries were and are worthy of special support, is not the ocean cable

industry still more so, since its product will multiply the mobility of our navy, foster and increase American trade with our own and foreign possessions, and put the nation on an independent footing for the means and materials of telegraphic communication in times of war, the lack of which, at a critical time, might involve national humiliation and the loss of many millions of dollars?

TRANS-ATLANTIC CABLES.

The first trans-Atlantic cable was completed in August, 1858, but ceased to work after about 400 messages had been transmitted; it contained 107 pounds of copper and 261 pounds of guttapercha per nautical mile. Not until 1865 was another attempt made to lay a cable across the Atlantic, but a number of mishaps occurred, and it was only in July, 1866, that a third attempt resulted in the successful laying of a cable across the Atlantic, and the completion of the 1865 cable occurred two months later; from this date the pioneer stage of ocean telegraphy may be said to have ceased. Since then many more cables have been laid across the Atlantic, there being now sixteen or seventeen, of which the first three or four have been abandoned, and the remainder are in service, including the so-called German cable, which was laid in August of last year, via the Azores; excluding the latter, they range from 1837 to 2563 miles in length, contain from 350 to 650 pounds of copper, and from 300 to 400 pounds of guttapercha per nautical mile; their actual speed of working, in five-letter words, ranges from 20.2 to 47.4 words per minute, the latter speed being obtained on the Anglo-American Company's 1894 cable of 1850 nautical miles, the core of which contains 650 pounds of copper and 400 pounds guttapercha per mile. It is a little over an inch in diameter, and weighs approximately two tons per nautical mile.

Capt. George Owen Squier has pointed out the fact that at the present commercial rate from Washington to Manila, $2.38 per word (the government rate being $2.255 per word, and the rate for "right-of-way" messages three times the nominal rate) the Pacific cable would only need to be operated 50 minutes out of each day in order to earn the annual income of $850,000, which he estimated as the cost of maintenance and repair, including operating expenses, reserve fund, and interest on capital; and that, reducing the present rate one-half, the cable would have to work less than two hours daily; also that if the cable could be kept busy (and he believes that in the not distant future it would be) up to its full capacity of paying words of eight letters each, there would be transmitted about 11,800 words at an average cost of about 7⅓ cents per telegraphic word.

ANENT ACTION OF CONGRESS.

At the first session of the present Congress the United States Senate passed a bill for a government-owned cable of American manufacture, but it makes the American clause inoperative by providing in effect, that if any foreign manufacturer offers the cable at a price 12 per cent. below the American manufacturer's price, it shall be bought abroad. This is an unfortunate and unjust proviso, and it is not believed that the Senate will insist upon it, in view of the fact that the Dingley bill, passed by a Republican Congress after mature deliberation, provides 40 per cent. protection to American manufacturers of such products; and the further fact that the American labor cost is 50 to 75 per cent. higher than the foreign, and the cost of some of the raw materials of cable manufacture (notably the iron armor wire) is from 25 to 35 per cent. higher than the foreign maker pays. Over and above this, a fair inducement must be offered to American manufacturers else they cannot afford to, and will not, make the necessarily large investment in plant and material that is involved in the establishment and prosecution of so great an industrial enterprise.

The House committee declined to adopt the Senate bill, but reported two bills of its own; one for private ownership, with a twenty years' subsidy of $300,000 per annum, and another (the Corliss bill) which corresponds in general with the bill passed by the Senate, except that it requires the cable to be of American manufacture, subject only to the condition that the first section (San Francisco to Hawaii) may be bought abroad if American manufacturers cannot produce it within a given time.

Financial

THE COMMERCIAL IMPORT OF LOAD FACTOR.

HARDLY an issue of *The Electrical Engineer*, of London, appears that does not contain some contribution of especial merit in its columns of "Questions and Answers," and in a late number* an initialed correspondent, "R. M. W.," discusses the influence of load factor upon the commercial results in long-distance electric power transmission. This commercial result, he states, depends on the relation between the total annual income and the total annual expenditure. Taking the percentage dividend as the measure of the commercial result, we have

$$\text{D per cent.} = \frac{\text{Profits (annual)}}{\text{Capital}} \times 100.$$

Now, the capital does not in the least depend on the load factor, and may be taken as constant. It is, therefore, the profits with which we have concern. The annual profits from a supply undertaking are equal to $I - E$, where I denotes the total annual income, and E the total annual expenditure. Now, let F denote the load factor, which is the ratio between the total number of units generated in a given time, to the maximum number of units which the whole of the generating plant could produce during that time. Let N denote the total possible output of the plant for a year in units; then

$$I = \text{price obtained per unit} \times N \times F.$$

The price obtained per unit, P, does not depend on F, but depends on the prices charged for steam, gas, or water power in the district supplied, as these competitive prices would determine the charge which could be obtained for electric power.

Now, E = cost of production per unit $\times N \times F$;

$$= \frac{S + (G \times N \times F)}{N \times F} \times N \times F;$$

$$= S + (G \times N \times F);$$

where S = total standing charges per annum, consisting of interest on capital, depreciation, sinking fund, rents, rates and taxes, salaries of officials, and all sundry expenses which do not vary with the number of units generated in the station. S is not dependent on the load factor. G denotes generating cost per unit, and may be taken as independent of F. Of course, in the case of long-distance transmission the loss in the line would be greater with a high load factor, as the cables would be working up to nearly their full capacity, and G would thus be increased. This cable loss would vary as F^2 (approximately). Although G would be increased owing to a loss of efficiency in the cables, it would be decreased to an almost equal extent by increased efficiency of boilers, engines, dynamos and station attendance, so for all practical purposes we may consider G independent of F, but of course dependent on the cost of coal (or whatever source of power is used), oil, repairs, maintenance and attendance at generating station, and for distribution, if the latter is done at the supply undertaking's expense. We have, therefore,

$$\text{D per cent.} = \frac{I - E}{\text{capital}} \times 100$$

$$= \frac{(P \times N \times F) - [S + (G \times N \times F)]}{\text{capital}} \times 100.$$

This formula denotes how the commercial result depends on the load factor. Of course, $N \times F$ is simply the total number of units sold per annum (F being calculated for a period of one year in the above case), and it will be seen that this varies directly as the load factor.

The Power Quarterly is the title of a publication brought out by The Power Publishing Company on October 15th last. Its first issue is a "gas engine edition," consisting of nearly 70 pages of solid, thorough and trustworthy information about the theory and practice of gas engine building and operation. Its convenient size (8x11 inches) and its authenticity are the first impressions received from it. It is destined to rank with its prototype, *Power*, in the high estimation of steam and mechanical engineers.

The Electrical Engineer, London, Vol. XXVI, page 921, December 28, 1900.

Transportation

THE SAXTON STEAM DRAY.

BY GEO. P. LOW.

AUTOMOBILISM has of late developed along lines that were quite unexpected when, a few years ago, the advent of the "horseless carriage" threatened to depreciate the value of horseflesh. France strives, with absinthic idiocy, to make racing machines that will seemingly distance thought in speed; England and Germany are producing autos that would not be half bad were they not such lumbering contraptions, and our American manufacturers, following original lines, have catered to the wealthier classes, and in so doing, have brought out machines that are the acme of grace, elegance, comfort, reliability and safety. All this has been done in a remarkably short time and now fertile brains are looking in other directions for avenues wherein they may make application of the locomobile to the enhancement of industry and profit.

Joe C. Saxton is a San Franciscan who has devoted much time and a very comfortable fortune to the development of a special variety of automobiles, namely, that for the handling of merchandise and heavy freighting either on city streets or along country thoroughfares. He early realized that horseflesh does not constitute a very efficient motive power when considered upon the basis usually applied in determining the worth of energy. Its serious inefficiency is, of course, offset by its great convenience, but were animal power efficient, the century which has just closed would not have witnessed its practical abandonment in all forms of modern industry excepting mainly that of local traction. Even in the latter, its efficiency is increased, as stated, only by the single factor of convenience, to secure which a very high price is paid. And this price may, indeed, be regarded as the penalty which must be paid for ignorance of the advantages of automobilism.

A 6000-POUND STEAM DRAY, BUILT BY JOE C. SAXTON, SAN FRANCISCO.

These and kindred reasons led Mr. Saxton to begin a line of experimenting with the end in view of perfecting an autovehicle of sufficient endurance to stand the strains of continuous heavy freighting service upon all kinds of travelable roads and of such construction as should be least liable to accident, or which, accident having occurred, could be most easily repaired by any cross-roads blacksmith. The high value of the gasoline engine as a source of power led to its use in the earlier forms of autotrucks built by Mr. Saxton, but it was abandoned in favor of steam for the reason mainly that steam engines may be built in the utmost simplicity and, being simple in construction, their care and operation is quickly acquired if not almost universally already understood. Again, being simple, repairs if necessary, may be the more readily made.

The Saxton steam dray, as the final form of Mr. Saxton's autovehicle is called, is built with these ideas always paramount. The finished machine is not a pleasure carriage; it is a heavy truck or dray built for hard, continuous work. Its boiler is of the plain "donkey" type, fired with California crude oil; its engines are of the equally plain locomotive link type, such as have been used in railroad work almost from its beginning. These mechanisms are tried and true and may be relied upon as one may trust his watch.

The steam dray here illustrated is, therefore, a very interesting mechanism. Its length over all is 15 feet 6 inches, and its extreme width is 4 feet 10 inches. Two five-inch I-beams weighing 10¼ pounds per foot, run longitudinally, upon which are placed one-inch plank. The wheels have a diameter of 38 inches and the bed, which is 14 inches deep, will clear an obstacle that is 19 inches above the street. The equipment complete with oil tank, water tank and boiler full ready for service, weighs 5000 pounds and it will carry a maximum load of 6000 pounds.

The boiler, which has a diameter of 30 inches and is 36 inches high, contains 140 1¼-inch tubes 24 inches long. No door is provided to the firebox which is, therefore, closed in; but future machines will be provided with a door so that oil, wood, coal or coke may be burned. The firebox is 12 inches deep and around it is carried a water leg through which the feed water is carried and given further heat in addition to that from the heater. As stated, the fuel used on this machine is California crude oil, burned through a patented burner which in itself is a decided innovation in automobile practice.

Crude oil is carried in a wrought iron tank placed beneath the driver's seat. This tank is under atmospheric pressure from a small air pump operated automatically from direct connection to the shaft of the main engine. The oil is therefore forced to the burner by this air pressure, but before reaching the burner it is taken through a ¼-inch pipe down one of the fire tubes of the boiler into the firebox where the burner is placed. A high degree of superheat is thus obtained for the oil, and the steam for the burner is similarly superheated, for it as well traverses down a fire tube through a ¼-inch pipe. The flame, which is of course intensely hot, is regulated manually by means of valves placed in

the oil and steam supply pipes close to the main throttle, and when the proper adjustment has been reached the oil burns without smoke.

Twin engines, each having a cylinder measuring 4x6¾ inches stroke, are used. They are of the plain slide-valve link variety made to conform, as stated, with the oldest and most trustworthy locomotive practice. All parts have been made of almost abnormal strength. The crank-shaft for instance, has a diameter of two inches, and the diameter of the connecting rods is 1¼ inches. Self-oiling grooved bearings are used throughout and the crossheads of the engines are babbitted. As is the case with the pipes supplying the burner with oil and steam, the steam for the engines is taken down through another of the fire tubes through ¾-inch pipes, each engine having a separate pipe although controlled by a single throttle. By this means the steam is superheated to such a degree that it always reaches the engines perfectly dry however much the autovehicle may have been shaken or however thoroughly the inlet of the steam pipe may have been flushed.

Variable differential gears are used either on the countershaft or on the gears direct as desired. In the present machine they are mounted on a small but staunch countershaft and the extreme range of variation in the gearing is four to one for speed and twelve to one for power. The speeds are changed by a clutch lever. Either sprocket wheels or cog gearing are provided, but the present machine is equipped with the former which runs noiselessly and has a high factor of safety.

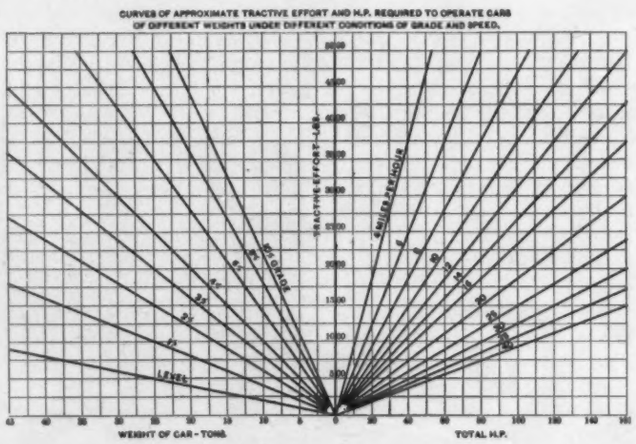
That which might be termed the auxiliary apparatus for the outfit consists of a small steam boiler feed pump, an injector, a hand air pump for applying air pressure to the oil tank, a condenser of special form which acts as a feed-water heater and abates the exhaust nuisance with surprising simplicity, an oil tank having a capacity of 42 gallons, and a water tank having a capacity of 125 gallons. The products of combustion are driven through the smokestack by part of the exhaust, while the remainder of the exhaust is thrown into the condenser beneath the truck.

As to the performance of the steam dray, it may be said that the engines have a rated speed of 400 revolutions per minute, although they have been run under test in actual service to a speed of 700 revolutions per minute. The speed of the machine when set to a gearing of maximum speed under normal duty is about 25 miles per hour. The outfit, when unloaded, experiences no difficulty in climbing an 11 per cent. grade with the high-speed gearing, and with the low-speed gearing when under load, it is undoubtedly safe to say that its ability to climb grades will find a limitation only in the adhesive effort of the wheels. As an instance may be cited a test given where with a load of 3000 pounds on the rear wheels, the rear wheels were lifted on top of and over a 12x12-inch timber against which they were originally at rest. Furthermore, a ten hours' test of the dray in actual service in freighting duty in San Francisco with the usual stops for loading and unloading, etc., and during which 28 miles were traversed under load, showed an oil consumption of 16 gallons, or a travel of 1¾ miles per gallon of oil consumed; while in a 52-mile run from San Francisco to San Jose, the fuel consumption was 1⅔ miles per gallon of oil. The fuel costs on these two runs were, therefore, $1\frac{7}{10}$ and $1\frac{8}{10}$ cents per mile respectively.

The Saxton steam dray is an auto that rides with remarkable comfort and, more surprising still, is the astonishing ease with which its two tons or so of weight is handled. Its speed is under the absolute control of the driver through the cut-off links, the manipulation of which gives the speed, direction or braking effort desired. The dray is not provided with wheel brakes, and such confidence does the builder have in the efficacy of reversing the engines for braking that he has repeatedly taken loads of from one to two tons down grades of from eight to ten per cent. with only reversed engines to brake with. Machines going into the hands of other operators will, however, be provided with brakes. While the machine was designed chiefly for freighting, its adaptability to stage-coach duty has been successfully demonstrated.

COST OF TRANSMISSION CONDUCTORS.

IN order to determine the best potential for an electric power transmission it is necessary to consider carefully the cost of the transmission circuit. The weight of the electric conductors decreases as the square of the potential employed, and increases as the square of the distance. Dividing the potential by the distance gives a convenient figure which can be used for all potentials and distances. The accompanying curves, which are those adopted by the General Electric Company and are taken by permission from Bulletin 4239, are derived in this way and


CURVES OF APPROXIMATE TRACTIVE EFFORT AND H.P. REQUIRED TO OPERATE CARS OF DIFFERENT WEIGHTS UNDER DIFFERENT CONDITIONS OF GRADE AND SPEED.
TRACTIVE EFFORT—LBS.
AMPERES PER MOTOR
LEVEL
WEIGHT OF CAR - TONS.
TOTAL H.P.

furnish a ready means of obtaining the amount of copper required for a given power transmission. For convenience the curves are further explained below and an example is given to show their application.

The figures on the curves indicate volts per mile; *i. e.:* the potential of the line at the generator divided by the distance in miles. The weight of copper, potential and line loss are in terms of the power delivered at the end of the line, and not of generated power. The curves are correct only for three-phase current with 100 per cent. power factor. Two-phase, single-phase or continuous current transmission requires one-third more copper. Five per cent. has been allowed for sag, in weights of copper given.

Example: Assuming that 1000 kilowatts at 10,000 volts are to be delivered over a line 10 miles long with 5 per cent. line loss, we have $\frac{10{,}000 \text{ volts}}{10 \text{ miles}} = 1000$ volts per mile. Looking on the 1000-volt curve, we find 5 per cent. line loss corresponds to 57 pounds of copper per kilowatt delivered.

1000 kilowatts × 57 = 57,000 pounds. If copper costs 20 cents per pound, the cost will be 57,000 × $.2 = $11,400.

25,000 VOLTS ON UNDERGROUND CABLES.

RECENTLY the water power of Apple River, in Wisconsin, has been used in an electric transmission at 25,000 volts to the city of St. Paul, twenty-seven miles distant. Especial interest therein rests in the method adopted for taking the high-tension circuits into the business center of St. Paul. The overhead transmission line ends at a second lightning arrester station near the eastern limits of the city, whence the high-tension current is carried underground by cable three miles further to the distributing station. The cables are two in number, one insulated by rubber and the other by prepared paper and either is of sufficient carrying capacity for the entire load.

These cables, which are lead sheathed, are carried in four-hole vitrified duct laid in concrete, and each consists of three conductors which are composed of seven strands of copper wire having an aggregate area of 66,000 circular mils per conductor. The installation is fully described in current engineering publications.*

*Notably *Transactions American Institute Electrical Engineers*, Vol XVII, Nov., 1900, and *Cassier's Magazine*, Vol. XIX, No. 4, page 243.

Generation

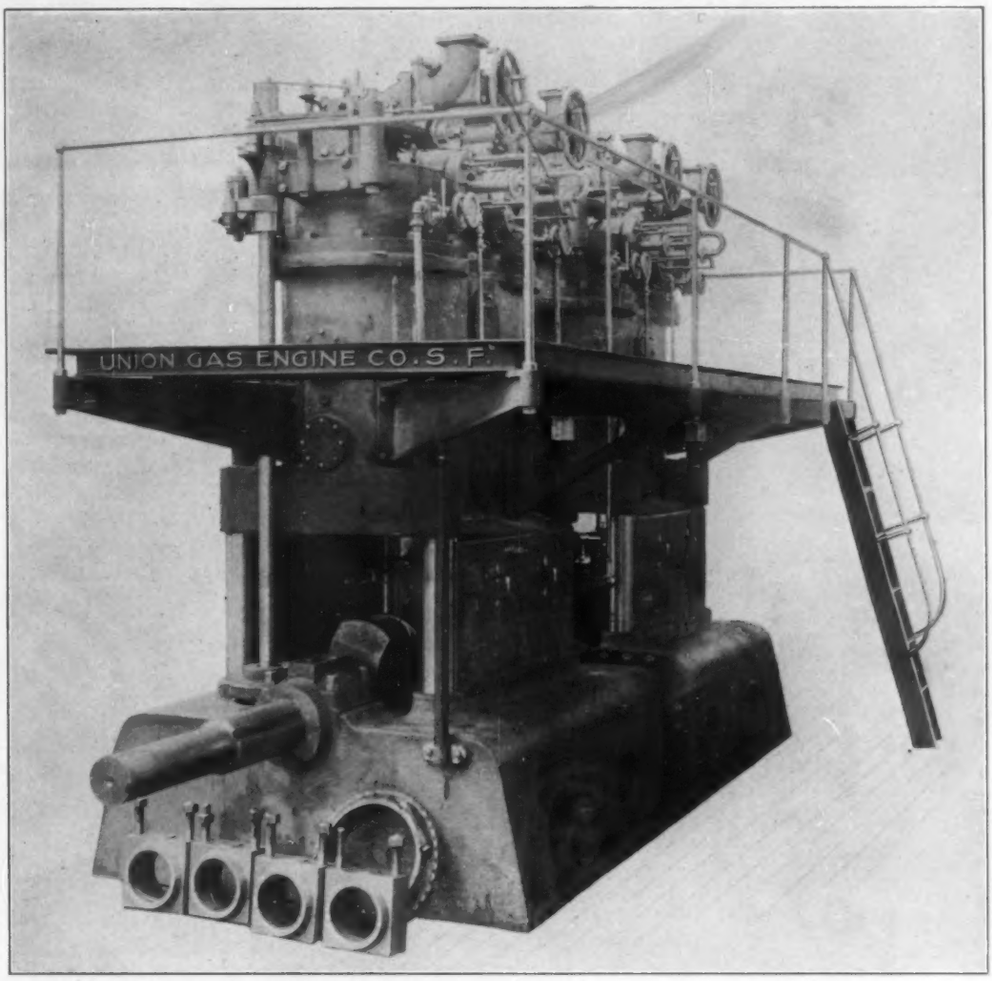
THE 360-HORSEPOWER "UNION" GAS ENGINE.

FULL details of the large gas engine which the Union Gas Engine Company of San Francisco is under contract to erect for the San Francisco Gas and Electric Company, have been published in these columns,* and interest therein will be heightened when it is known that the engine has been completed and is now being set up in Station B of the gas and electric company named.

Herewith is given a shop view of the finished engine which, though as yet the largest that has been built on the Pacific Coast, will, in all probability, soon be exceeded in size, as the Union Gas Engine Company expects to shortly place 500-horsepower engines on the market.

The engine here illustrated is to deliver 360 estimated horsepower, and it will drive, through direct connection, a 200-horsepower generator. The approximate weight of the engine is 50 tons; its length over all is 29½ feet; its width is 8 feet 2 inches and its height is 12 feet 9 inches.

The engine is of the four-cylinder type, and so arranged that one or more cylinders can be cut out even while the engine is in operation. A self-starting device is connected to each cylinder, and the manufacturers say this engine will regulate within 2½ per cent., but complete details of its actual performance will be given in the columns of THE JOURNAL as soon as they have been obtained.



THE 360-HORSEPOWER GAS ENGINE BUILT FOR THE SAN FRANCISCO GAS AND ELECTRIC COMPANY.

*THE JOURNAL, Vol. X, pages 69-70, September, 1900.

THE USE AND CARE OF PLATINUM.

BAKER & CO., manufacturers of platinum for all purposes, and whose works are located in Newark, N. J., have issued an artistic vest-pocket memorandum book in celluloid cover that contains considerable useful information of a general trend, as well as much which pertains to the use, care and properties of platinum. It points out the importance of remembering that although platinum is not oxidized in the air at any temperature, nor attacked by any single acid, yet there are many substances that attack and combine with it at comparatively low temperatures. The caustic alkalies, the alkaline earths, nitrates and cyanides, and especially the hydrates of barium and lithium, attack platinum at a red heat, although the alkaline carbonates have no effect at the highest temperatures. Sulphur, in the absence of alkalies, has no action, but phosphorus and arsenic attack platinum when heated with it. Direct contact of platinum with burning charcoal should be avoided since the silicon reduced from the charcoal ash unites with platinum, making it brittle and liable to fracture. Also contact with compounds of the easily reducible metals is especially dangerous at high temperatures, as alloys with platinum having a low fusing point are readily formed. This is especially true of lead.

Heating of platinnm with spirit lamps is preferable to the use of ordinary gas. When gas is used care should be taken to have the supply of air sufficient to insure complete combustion, since, with a flame containing free carbon, the platinum suffers deterioration by the formation of a carbide of platinum which, oxidizing later, blisters the metal. For this reason also, the inner cone or reducing flame should not be allowed to come in contact with the metal.

The loosening effect of the Bunsen flame upon the surface of platinum exposed to its action produces the familiar gray appearance which cannot be removed except by burnishing. Platinum triangles often become gray and very brittle from the same cause. Systematic application of moist sand to all articles affected in this way, after use, will keep them in prime condition and materially prolong their life, with but a trifling loss in weight.

Phosphorus is obtained electrolytically in Germany from the electrolytic decomposition of phosphoric acid and charcoal. Direct current is applied at 120 volts and in the Dile process the current consumption is from 80 to 150 amperes.

Literature.

"PROGRESS OF INVENTION IN THE NINETEENTH CENTURY," by Edward W. Byrn, A. M. Large octavo; 480 pages; 300 illustrations. Price, $3.00; half red morocco, gilt top, $4.00. Published by Munn & Co., 361 Broadway, New York.

Readers of the *Scientific American* are aware to what extent it has devoted itself for more than half a century to chronicling the inventions and discoveries of the century, and it is fitting that its publishers should bring out a volume to commemorate the completion of the nineteenth century. The book presents in concrete form the great scientific and engineering achievements of the century and records and describes all the important developments of the arts and sciences which distinguish the period. The work gives a most comprehensive, compact and coherent account of the progress which distinguishes this as the "golden age of invention," resulting in industrial and commercial development which is without precedent. It is a book which can be confidently recommended to a general scientific public.

A chronological table of leading inventions is one of the important features of the work, and it enables the reader to ascertain at once the most important inventions and discoveries of any particular year. It may be learned at a glance, by examining this calendar, that in the year 1832 Morse invented the electric telegraph, but that in the year 1831 Henry had transmitted signals telegraphically. It will be seen that in the year 1876 Gray and Bell invented the speaking telephone, and in 1877 Edison invented the phonograph. It will also be seen that in the year 1815 Sir Humphrey Davy invented the safety-lamp, in 1821 Faraday converted electric current into mechanical motion, in 1885 Cowles introduced his process of manufacturing aluminum, and in 1896 Marconi devised his system of wireless telegraphy. These are a few examples taken at random from the list which covers one hundred years of invention. This list must not be confounded with the general classification by subject matter which comprises the principal part of the work. The author has devoted a considerable period of time and careful study to its preparation, and he is specially qualified for the work owing to scientific training of a high order and many years of practical experience in such matters. He deals with the subject in a masterly manner, citing United States and foreign master patents, thereby giving the best authority for the statements made, as they are based on official records. This has never before been accomplished, and the result is a book which will always be of sterling value and which will at once take rank as a work of reference. The book is, withal, very interesting, and will prove an addition to any library. It is printed with large type on fine paper and is elaborately illustrated.

A HANDBOOK OF THE TELEGRAPH, by A. E. Loring. Fourth edition, revised. No. 39 of Van Nostrand's Science Series; 110 pages; 3¼x6⅞ inches; cloth. Published by D. Van Nostrand Company, New York, 1900. Price, 50 cents.

In all the applications of electricity there is no more simple one in its basic principles than that of the telegraph; yet while it is so simple fundamentally, there are comparatively few who can explain the principles of duplex and quadruplex telegraphy, for instance, or even those of the automatic repeater. Mr. Loring's explanation of these and all other general matters connected with telegraphy, presents the subject so clearly that all may understand. The little book is prefaced by such a discussion of the principles of electricity and magnetism as will be necessary to a proper understanding of the subject, and it is supplemented with suggestions and exercises for learners.

TRADE LITERATURE.*

General Electric Bulletins. No. 4239, "Polyphase Machinery" of General Electric types is described, together with a more or less elementary discussion of the principles, types and general characteristics of polyphase lines and apparatus. It is an excellent bulletin. *General Electric Company.*

Westinghouse Bulletins. No. 1038, "The Westinghouse No. 49 Railway Motor," and No. 1039, "The Westinghouse No. 38B Railway Motor," are described with general discussions of the individualities of street railway motors as a class, as well as of the mechanical construction and data of these particular types. *Westinghouse Electric and Mfg. Co.*

"Ideal" Bulletins are issued frequently in a form that represents not only the height of the printer's art, but also the acme of succinct description. The many invaluable improvements to be found only in "Ideal" engines are shown, and in some bulletins, such as those on central-station type (No. 42) and railway type engines (No. 43) complete specifications with performance data are given. The "Ideal" Governor (No. 45) is of value to every steam engineer, whatever be the make of engine he is using. *A. L. Ide & Sons*, Springfield, Ill.

"Price List No. 21, New York Insulated Wire Company," is a coat-pocket handbook that is replete with information concerning telegraph, telephone, electric light and housework wires and cables, electric railway feeders, insulating tapes and compounds. It contains, for instance, excerpts from those portions of the rules of the National Board of Fire Underwriters as pertain to wires and cables, as well as convenient forms of wiring tables that are indispensable to electricians. All sizes and brands of wires, such as the well-known Grimshaw and Raven white cores, the Raven black core rubber wires and the Competition line wire, etc., are fully specified in a form that is concise and thoroughly convenient. *New York Insulated Wire Company*, 33 Second street, San Francisco.

"Ericsson Telephone Instruments and Plants," is the title of the superb fourth edition of the general catalogue published in English, German and French simultaneously by L. M. Ericsson & Co., the celebrated telephone manufacturers of Stockholm, Sweden. The book, which is bound in stiff boards, measures 9x11¼ inches, and contains 125 pages that are illustrative and descriptive of the very best European types of telephone, telegraph, fire-alarm and sundry apparatus, among which latter are instruments of precision. One of the plates therein is an exquisite photogravure of a 10,000-subscriber exchange using Ericsson apparatus in Stockholm, which shows the perfect blending that is possible between art in architecture and utilitarianism in engineering. Would that there were more of this in America. *Ericsson Telephone Company*, 293 Broadway, New York.

"Pumping Machinery" is the title of the third edition of catalogue No. 10 (1900), the contents of which is explained in its title. It is a book of 120 pages, 7x10¼ inches, and is descriptive of pumps of every known class, all of which are of Risdon build. The fact is that conservatism is responsible for the prevalent belief shared in by practically all except those within specific lines, that the Pacific Coast has really advanced but a tithe toward the pinnacle that has been reached by the most prominent of machinery manufacturers in the East. Occasionally some extraordinary performance, such as the trip of the Oregon, or the unwatering of the Comstock mines, bring Pacific Coast manufacturers into prominence; but it needs only a glance at such a catalogue as that under consideration to show that in points of varieties of service, skill in workmanship, and both quality and quantity of output, some Western concerns are fully abreast with any advance that has been made by their Eastern brethren. Aside from many engineering tables and considerable matter of an educational vein, the book describes many special pumping devices, principal among which should be named Joseph Moore's Patent Hydraulic Pumps, compressed air pumps, air lifts, Cornish systems and the Evans Hydraulic Elevator. The price of the book is 50 cents. *Risdon Iron Works*, San Francisco.

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